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ABSTRACTS
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IDENTIFICATION OF CRYSTALLINE SUBSTANCES BY MEANS OF X-RAYS*

By B. E. Warren

ABSTRACT

Methods of preparing X-ray diffraction patterns of crystalline materials, the significance of an X-ray diffraction pattern, and its relation to the sample material are presented. Methods are also given for identification by (*a*) direct analysis of pattern, and (*b*) comparison with diffraction patterns of known materials. Difficulties in classifying and cataloging diffraction patterns are listed. The identification of a completely unknown material is therefore, in general, not possible. Except in special cases it is necessary to have some additional information such as an approximate chemical composition. Difficulties in identification are encountered when more than one crystalline compound is present.

The advantages of X-ray diffraction identification are as follows: (*a*) a definite crystalline modification is identified (not simply a chemical compound or chemical composition); (*b*) sharp differentiation between crystalline and amorphous or glassy modifications; (*c*) identification of different components when individual grains are submicroscopic in size; (*d*) the diffraction pattern consisting of a large number of lines which must fit the known pattern both with respect to the positions of the lines and their relative intensities; considerable data are available, and hence the identification by an X-ray diffraction pattern is, in general, very definite; and (*e*) the production of an X-ray diffraction pattern is very simple.

I. X-Ray Diffraction in a Crystal

In the crystalline state a small group of atoms or molecules comprising what is called the "unit cell" is repeated identically at regular intervals in three dimensions, building up a space lattice. So far as X-ray diffraction is concerned, such a lattice can be conveniently considered in terms of the large number of sets of parallel equidistant planes which it defines. Figure 1*a* is a schematic representation of a two-dimensional crystal, the two atoms *a* and *b* being repeated identically at regular intervals in two dimensions. A set of equivalent points in the lattice is represented by the small crosses, and it is obvious that through these crosses it is possible to pass sets of parallel equidistant planes in a large number of different ways, each set of planes having a definite orientation and spacing, d. The theory of the diffraction of X-rays in a crystal shows that if an X-ray beam of wave-length λ falls upon a crystal making such an angle, θ, with a set of planes of spacing, d, that the Bragg law, $\lambda = 2d \sin \theta$, is satisfied, a diffracted beam will be formed. (Fig. 1*b*.) The diffracted beam will also make an angle θ with the set of planes, and will hence make an angle 2θ with the primary beam.

II. Powder Patterns

The materials which are of interest in the ceramic field are generally obtainable only in the fine-grained state, and for material in this form the "powder method" is best suited. Figure 2 represents a Debye-Scherrer-Hull type of powder-diffraction camera. The material is ground to a fine powder (200-mesh or more) and then made up into a cylindrical sample by filling into a thin-walled tube of glass or paper or by coating onto a thread with collodion.

The radiation from the X-ray tube passes through a thin filter which transmits the strong Kα-line and absorbs markedly the other wave-lengths, so that an essentially monochromatic beam is produced. This beam is collimated by passing through a tube of about 1 millimeter bore and then falls upon the cylindrical powder sample. The individual crystals in the sample have all possible orientations, and hence for every set of planes of spacing d, there will be some crystals so oriented as to make just the right angle θ with the incoming X-ray beam to allow the Bragg law to be satisfied and a diffracted beam to be produced. Those crystals which make the proper angle for a given set of planes may of course have any orientation around the direction of the primary beam, and hence the diffracted beams from a given set of planes form the elements of a cone of half-apex angle 2θ. For each family of planes of spacing d, there will be a cone with corresponding half-apex angle 2θ. The intersection of these cones with the photographic film gives the typical curved powder-pattern lines.

Calling s the distance on the film from a line on one side to the corresponding line on the other side, then

$$\frac{s180}{R\pi} = 4\theta \text{ (degrees)}.$$

* Presented in the Symposium on Crystalline Substances in Refractories, Annual Meeting, American Ceramic Society, Cincinnati, Ohio, Feb. 13, 1934 (Refractories Division). Received Feb. 19, 1934.

Since λ is always known, we can then substitute directly in the Bragg law, $d = \frac{\lambda}{2 \sin \theta}$, and obtain the value of the spacing, d. The direct data which one obtains from any diffraction pattern is thus a set of values of spacing d for all the lines on

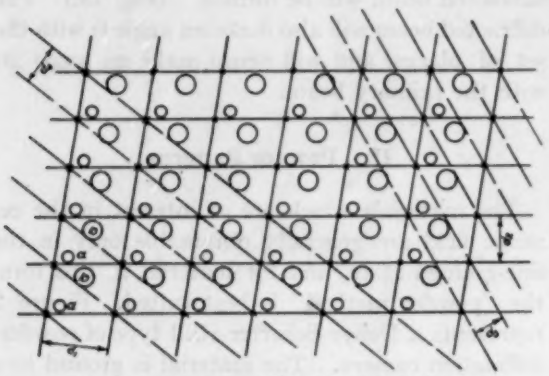

FIG. 1*a*.—Representation of crystal planes.

the diffraction pattern, together with the relative intensities of the lines.

III. Special Technique Involved

A certain amount of technique is involved in the preparation of satisfactory powder patterns. The powder must be well ground (otherwise the lines will be ragged and speckled), the diameter of the cylindrical sample must be small if sharp lines are desired, and the container or supporter of the

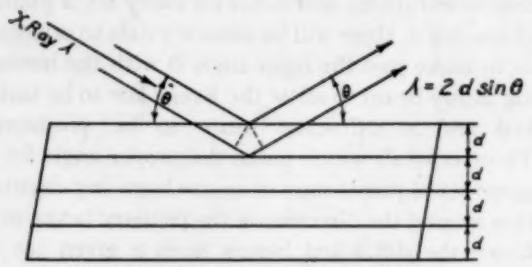

FIG. 1*b*.—Diffraction by crystal planes.

sample must be so chosen and prepared that it does not give rise to stray lines. Assuming that more than one source of radiation is available, the kind of radiation to be used should be carefully chosen with respect to the sample. Radiation should not be used for which the wave-length is just less than the absorption edge of any principal element in the sample. For example, the commonly used CuKα-radiation should never be employed with any sample containing large quantities of iron. Other things being equal, it is generally better to use the longer wave-lengths CuKα, FeKα since radiation of long wave-length spreads the pattern out and makes easier an accurate measurement. In addition, the photographic film is much more sensitive to long wave-length radiation, and hence the time of exposure is cut down markedly. If the absorption coefficient of the sample material is at all large, it is often necessary to dilute the sample with some light substance such as cornstarch. Unless this is done, the diffraction takes place solely on the surface of the sample, and hence leads to incorrect spacing values.

Perhaps these few examples will suffice to show that not only the interpretation, but also the

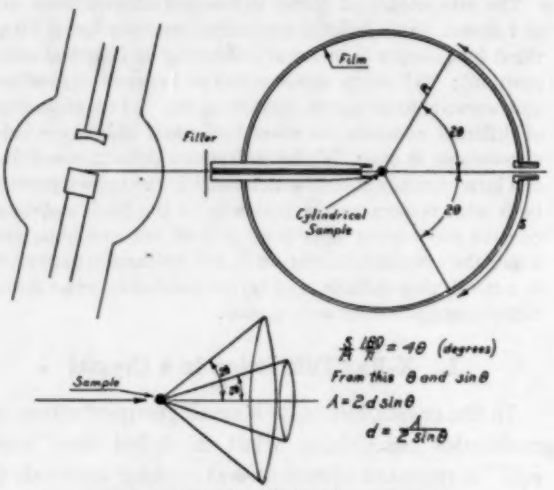

FIG. 2.—Powder-diffraction camera.

preparation of diffraction patterns requires a specialized technique, and that unless this sort of work is done by a person trained and competent in this specialized field, the results are apt to be unreliable and of but little use. It is unfortunate that so many industrial laboratories are willing to put four or five thousand dollars in a fine X-ray equipment and then suppose that a real economy can be effected by having the chemist's second assistant, or whoever else happens to be available, handle the X-ray work.

IV. Significance of a Powder Pattern

The powder diffraction pattern of a sample does not in any sense indicate either the chemical elements or the chemical compounds in the sample; *it is characteristic solely of the crystalline phases present.* This point is illustrated by the

diffraction patterns of SiO_2 in Fig. 3. The chemical composition in each case was SiO_2, but as seen in the patterns there is no similarity indicative of the common SiO_2 composition; the patterns are distinctly different, each one being characteristic of that crystalline (or noncrystalline) phase. If the sample is a mixture of more than one crystalline material, the diffraction pattern obtained will of course be a superposition of the individual patterns characteristic of each crystalline component.

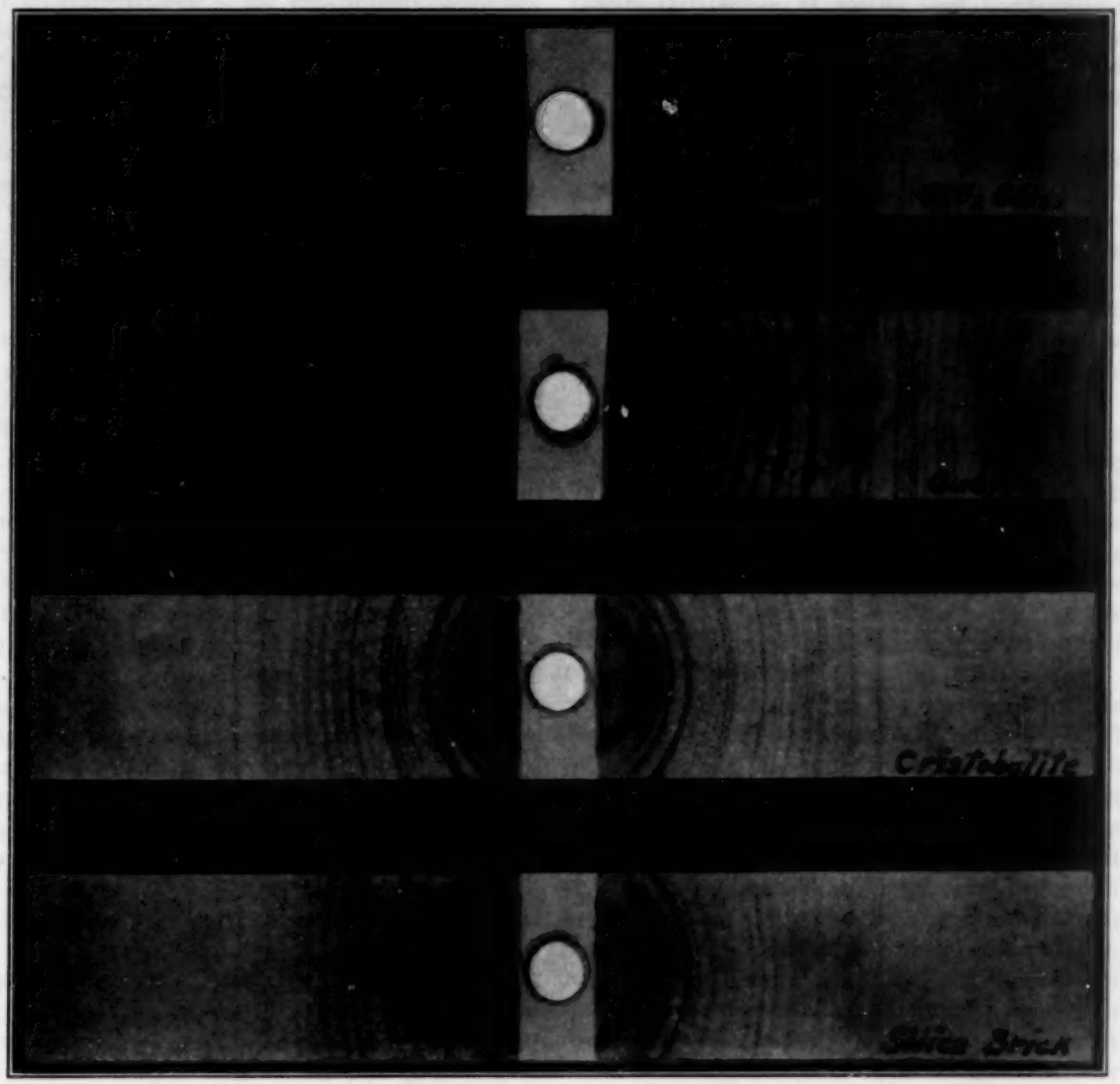

FIG. 3.—Powder-diffraction patterns of different forms of SiO_2. Reading from the top: vitreous silica, quartz, cristobalite; and silica brick.

V. Identification by Diffraction Pattern

To identify a material by means of its X-ray diffraction pattern, it is not necessary to work out the pattern. It is simpler and quite sufficient to compare the pattern with patterns of known materials until a complete match is found; by a "complete match" is meant an exact equivalence in both the positions and the intensities of the lines.

In general it is of course impossible to identify a completely unknown material by means of its X-ray diffraction pattern, since it would be necessary to have comparison patterns of all the thousands of possible substances. It is practically necessary that one have at least a rough knowledge of the chemical composition, in order

that comparison with only a reasonable number of known patterns would be necessary. *X-ray diffraction is definitely not a method for the identification of a completely unknown material;* it is most powerful as a method of identification of definite crystalline phases in a material about which enough is already known so that only a limited number of possible crystalline phases might reasonably be expected.

While this method of identification, by making up comparison diffraction patterns of the various crystalline compounds which might reasonably be present in the unknown material, is a reliable working method, it is nevertheless laborious and time-consuming. In the restricted field of identification of ceramic materials, it would be possible and desirable to develop a direct method of identification.

Including the natural minerals, the artificial crystalline phases, and the devitrification products of glasses, it is probably true that the number of different crystalline materials of interest in ceramic research would be well under 100. For such a limited number of substances it would be wholly feasible to make up a complete set of standard diffraction patterns, utilizing of course those that are already available and reliable.

By itself the diffraction pattern is not a convenient comparison unit, for there is no single feature which is distinctive or permits ready classification or cataloging. It is only the pattern in its entirety that has significance, and it would be as difficult and unsatisfactory to catalog diffraction patterns as to catalog Chinese characters, if totally ignorant of the Chinese language. A few laboratories have set out to build up complete libraries of comparison diffraction patterns of standard materials, and while this is a very necessary first step, the direct comparison of films of unknowns with a library of standard patterns does not appear to be a generally satisfactory method of identification. Even if the classification problem could be satisfactorily handled, the direct comparison method becomes uncertain and unsatisfactory when the unknown contains more than one material, as it usually does.

VI. Spacing Table for Ceramic Materials

The obvious answer to the problem is a "spacing table," since the spacing is a definite numerical quantity and admits of ready tabulation. Assuming that the 100 standard patterns have been prepared, the spacings of all the lines would be carefully measured and then tabulated in order of decreasing value. Table I is intended to illustrate how such a table might be arranged.

TABLE I

ILLUSTRATIVE SPACING TABLE*

Spacing d A°	Name and Chemical Compound	Intensity		Indices
1.934	Quartz (SiO_2)	V.S	5	003
1.921	Alumina (Al_2O_3)	M	3	231
1.916	Sillimanite (Al_2SiO_5)	V.W	1	301
1.902	Cristobalite (SiO_2)	S	4	263
1.893	Albite ($NaAlSi_3O_8$)	W	2	410
1.872	Alumina (Al_2O_3)	S	4	333

* The numerical values in this illustrative table have no significance.

With each spacing would be given the name of the material and its chemical composition, the relative intensity of the line on the standard pattern, and the indices of the line in case the unit cell has been worked out. It would be necessary that this work should be done with extreme care. Reliable standard materials must be used, the camera must be carefully calibrated, and correction for absorption and sample width made so that accurate spacing measurements can be given. The patterns must be carefully checked for stray lines such as those due to impurities or $K\beta$ not completely filtered out. Where the unit cell is already known and indices can be assigned, the spacings should be checked against the values given by the quadratic form. If the structure has been worked out, theoretical intensities should be calculated and compared with the observed intensities as a check on the data and to make sure that preferred orientation in the sample is not present.

With such a table at hand, the identification of an unknown material would be a relatively straightforward matter. The film would be measured up and the spacings of all the lines calculated. For each spacing value on the unknown, the different materials would be listed which have lines in the table which check the unknown line to within the experimental error. In general, more than one substance will appear to fit any single line; but if for the whole set of lines one substance appears each time as a possibility, then this is the unknown material and the other matches of different substances for different lines were chance coincidences. Even with two or three substances in the unknown sample, the identi-

fication would be nearly as simple and straightforward. When more than one substance is present, once the lines belonging to the different substances have been identified, it would be possible to draft immediately a rough estimate of the relative abundance of the constituents, since the intensities are listed in the table. For example, if among the other lines, there are three extremely weak ones which from the table are the three strongest lines of alumina, then one can conclude directly that a very small amount of alumina is present among the other materials.

The building up of such a spacing table for the ceramic materials is wholly feasible and to be strongly recommended. Once available, the identification of ceramic materials by X-ray diffraction patterns would become a relatively straightforward process. The power of the X-ray method in identifying the crystalline phases present, in conveniently recognizing the presence of more than one constituent in the unknown, and in working conveniently with material which is too fine grained for recognition with the microscope, could then be more fully utilized, and the X-ray method would become one of the simplest and most powerful methods for the identification of crystalline substances in the field of ceramic research.

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THE APPLICATION OF INSULATING MATERIALS TO INDUSTRIAL FURNACES*

By J. D. Keller

I. Classification of Insulating Materials

The refractory materials of which the walls of industrial furnaces are constructed are not particularly good insulators against loss of heat; in fact, their position in the scale of thermal conductivity lies closely adjacent to, if not actually within, that betwixt-and-between region which separates the materials classed as heat insulators from those classed as heat conductors. The loss of heat through the furnace walls is therefore a large item in the heat balance of a furnace, ranging from a lowest limit of about 20% of the useful heat (that which is transferred to the charge) to as much as 500%. On the average, it may be said, about as much heat is lost by conduction through the walls as is usefully employed in heating the charge.

With regard to this loss through the walls, one of three courses may be adopted. The first is to do nothing about it, taking the loss into the bargain as a necessary concomitant of high-temperature heating. The second course is to apply outside of the furnace walls materials which are considerably better insulators of heat than the refractories but which can not withstand as high temperatures as the latter. The third course is to depart from the use of the standard refractories altogether and to build the entire walls of the recently developed refractory insulating materials, some of which can withstand almost as high temperatures as first-quality fire brick. Sometimes, on account of operating limitations, the first course is the only one possible, but even where all are possible, no one of the three courses is the best in every case; each has a field in which it is the most economical when all items of cost are considered. Economy, however, is often secondary to other considerations, some of which will be mentioned later.

Roughly, the division of insulating materials into those used outside of refractories and those used in place of refractories coincides with the division into low-temperature insulators and high-temperature insulators, respectively. There are, however, exceptions. Some materials, for example, can withstand quite high temperatures but for other reasons are unsuitable for use inside of furnaces.

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* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February 15, 1934, as part of the Symposium on "Heat Transfer through Refractories and Insulation in Industrial Furnaces," organized for the General Session by members of the Refractories Division (Fred A. Harvey, Leader). Other papers presented in this Symposium are being collected and will appear in subsequent issues of the *Journal*. Paper received February 26, 1934.

II. Insulation Applied Outside of Refractory Walls

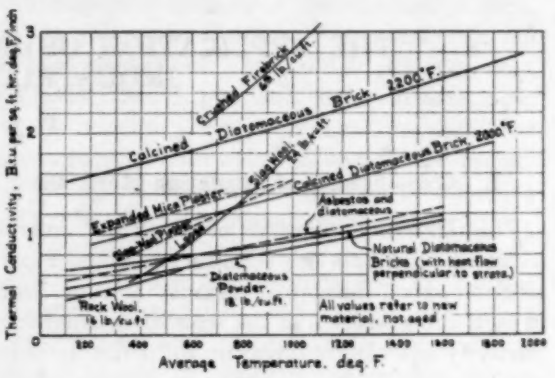
(1) Limiting Factors The application of insulation to the outside of refractory walls in high-temperature furnaces may be limited by the effect of temperature on the insulating material or more frequently by its effect on the refractories.

Reduction of the heat flow through the walls when insulation is applied does not, in general, increase the temperature of the inside surface of the refractory wall to an appreciable extent, but it does cause given temperatures to penetrate into the brick to greater depths; and if the furnace temperature is high enough to cause softening of the innermost layer of the wall, this soft layer becomes much thicker in the insulated than in the uninsulated wall and is therefore likely to drip or slough off more rapidly. Furthermore, both erosion by dust carried in the gases and more rapid penetration of fluxes, as in the open-hearth furnace, may, although they do not necessarily, cause quicker eating-away of the inside layers of the wall, and the margin of safety with regard to overheating by impinging flames is much less.

Both the rise of the temperature and the depth of penetration of high temperatures into the refractories may often be much more than would be expected from the insulating effect alone. This is due to the shutting-off of air infiltration by the insulating layer in parts of the furnace which are under draft rather than under pressure. The reduction of air infiltration often accounts for as great a saving of fuel as the actual reduction of heat flow through the walls, as in the case of open-hearth checker chambers. It may, on the other hand, make the use of insulation impossible because the temperature level is raised throughout the entire thickness of the wall. Thus, up to the last two years, it was considered that the downtakes and the bulkheads of open-hearth furnaces could not be insulated without causing their rapid destruction. (They are, however, now being insulated.)

The combined effect of temperature penetration and erosion is illustrated by experiences with insulation of the caps or roofs of the melting end of glass tanks in the few cases where this has so far been tried. As long as the cap remained tight the insulation had no bad effect, but as soon as a slight leak started in it, the gases underneath, being under considerable pressure and at very high temperature, spurted out at high velocity, carrying with them dust and fluxing vapors. Then the refractories, being at high temperature throughout, could not withstand the erosion, and the hole widened very rapidly. The gases found their way between the insulation and the top of the refractory and caused further overheating. The only way to save the roof after that was to remove the insulation at once from that section. There is no reason, however, why methods of sealing which will overcome this trouble can not be devised.

Aside from the effect on the refractories, the use of insulation may be limited by the temperatures which the insulating materials themselves can withstand. Each material has a limiting safe temperature, heating beyond which will result in fusion, excessive shrinkage, cracking, crumbling, sagging, or loss of insulating properties.


Thermal Conductivity, Btu per sq. ft. hr. deg F/inch
Average Temperature, deg. F
Crushed Firebrick 68 lb./cu. ft.
Calcined Diatomaceous Brick, 2200°F.
Sawdust 15 lb./cu. ft.
Calcined Diatomaceous Brick, 2300°F.
Expanded Mica Plaster
Asbestos and diatomaceous
Natural Diatomaceous Bricks (with heat flow perpendicular to strata.)
Diatomaceous Powder, 18 lb./cu. ft.
Rock Wool, 16 lb./cu. ft.
All values refer to new material, not aged.
FIG. 1.

The insulating materials most frequently used on the outside of furnace walls are diatomaceous earth (also called infusorial earth and kieselguhr); compositions containing asbestos together with diatomaceous earth; expanded mica; monohydrated bauxite; rock wool; slag wool; granulated slag; and granulated (crushed) fire brick. As a rule, the materials having the highest insulating value at low temperatures are unsuited for use on furnaces either because they deteriorate at moderate temperatures (for example, the materials used in cold insulation and those used for steam-pipe covering) or because in those which do not deteriorate the resistance to heat flow decreases rapidly with increase of temperature. In Fig. 1 are shown the approximate thermal conductivities of some of the materials as related to temperature. It should be remembered that

under heat all insulating materials increase in conductivity with age. In the diatomaceous brick this loss of insulating value is a serious item.[1]

The maximum allowable temperature of natural diatomaceous insulators is 1600°F. At somewhat above that temperature, the material shrinks badly and in some cases it even fuses. Rock wool is not recommended for use above 1200°F, and has been known to shrink at even lower temperatures.

The asbestos-diatomaceous earth composition has not been recommended for temperatures over 1600°F, and some users state that failures have occurred as low as 1200°F. The makers claim that recent improvements have produced a material which can withstand temperatures several hundred degrees higher.

Pure mica does not fuse below 2500°F, but the asbestos fibers and bentonite clay used as a binder in the expanded mica plaster cause fusion to occur at a considerably lower temperature. Shrinkage starts at about 1600°F and becomes serious at 1800°F. This material has, however, been used on open-hearth roofs in thicknesses which raised the interface temperature to 2000°F. It has the advantage that, even if fusion occurs, no fluxing action is exerted on the silica roof. Most kinds of blast-furnace slag wool do not deteriorate below 1600°F. Above this, the wool gradually sinters together, shrinks, and loses its insulating value. The same is true of granulated slag. (Crushed fire brick can, of course, withstand as high temperature as the brick of which it is made.) Where the interface temperature is likely to exceed 1600°F, pressed calcined diatomaceous brick may be used, some of which can withstand 2000°F, while their insulating value is not much reduced below that of the natural diatomaceous brick; others, calcined at higher temperature, are good for 2200°F, while the most refractory brick made of this material or of a mixture of it with clay can withstand 2500°F. Recently introduced porous clay brick have comparatively good insulating value and do not shrink appreciably up to 2500°, while those made of kaolin are good for 2700°F; the last-named brick, however, are quite expensive.

The highest temperature in the insulation, of course, occurs at the interface or the surface where the inside of the insulating layer touches the outside of the refractory wall.[2] It should, however, be remarked that some leeway or margin should be allowed between the calculated interface temperature and the maximum allowable temperature of the insulation for the reason that the thickness of the inner refractory wall may, after operation for some time, be reduced by spalling or by fluxing away, whereby the interface temperature may be raised several hundred degrees. The same effect may be produced by outward leakage of hot gases through the wall, if considerable pressure exists in the furnace, as in the glass tank already discussed.

To some extent, the reduction of insulating value on overheating acts in a self-regulating capacity. Thus, on some open-hearth furnace roofs, when an excessive thickness of slag wool has been applied as insulation, the increase of the interface temperature caused the lower layers of the wool to sinter practically solid or even to fuse, whereby the effective thickness was automatically reduced and the interface temperature dropped to the desired value. It is rather risky, however, to depend on this, first, because the sintering temperature may be higher than that at which the interface can safely be maintained with reference to the strength of the refractories of the roof, and second, because in some cases serious trouble has resulted from fluxing of the refractory by contact with the fused slag.

In many furnaces the life of the lining is limited by spalling rather than by melting or fluxing. Formerly it was thought that insulating the walls and roof would result in increase of spalling. Although there is still some difference of opinion, both laboratory spalling tests using large panels and observation of linings of actual furnaces have shown that insulating the furnace reduces spalling except in unusual cases.

Another factor which sometimes limits the use of insulation is lack of mechanical strength. It is

[1] Considerable variation is to be expected, due to variations in the materials as well as in details of the testing method. Lower values are often reported for each of the materials, but curves are believed to represent fair average values. They refer to new insulation, not aged. Tests were made of rock wool and of diatomaceous powder by L. B. McMillan, of natural diatomaceous brick and asbestos-diatomaceous blocks by McMillan at low temperatures and by R. H. Heilman at higher temperatures, and of slag wool by the author. Density of expanded mica plaster was 17 to 22 lb. per cu. ft.

[2] The method of calculating the interface temperature is fully explained in Trinks' Industrial Furnaces, Vol. I, pages 67 to 70, and need not be repeated here.

true that the weight which insulating brick in side walls and roofs have to carry is small. Nevertheless, the factor which prevents complete insulation of the sides (except in small furnaces) is lack of sufficient strength and especially of sufficient rigidity to withstand the thrust of the arch without yielding and to transmit this thrust to the buckstays. As far as the insulating material itself is concerned, crushing caused by the arch thrust would merely reduce it to powder, which is not objectionable if encased; but the lack of rigidity would permit the abutments of the arch to spread apart. Under no circumstances can this be tolerated because it would endanger the stability of the arch. The lack of strength is also one of the objections advanced against the use of insulation under hearths, where the weight of the charge in the furnace must be transmitted through the insulation to the foundation. Some builders of furnaces, however, have found that, provided fire brick are laid over the insulation to a depth of ten inches or more, even the natural diatomaceous brick can carry the load without trouble, except for extremely heavy concentrated loads. The courses of fire brick distribute the load over the insulation.

The low strength of insulating brick also results in a great amount of breakage in handling these expensive materials.

Where greater strength is required, as in hearths with very heavy concentrated loads, the high-temperature insulators previously mentioned may be used. These, however, for a given thickness have not over half of the insulating value of the low-temperature insulators.

(2) Practical Considerations in Applying Insulation

Roofs are usually easy to insulate as far as application is concerned, because gravity holds the material in place. For use on arched roofs, insulating brick can be obtained in wedge shape, insuring tight joints when laid in place over the arch. Most of the materials are so soft, however, that the edges of the standard $2^1/_2$- by $4^1/_2$- by 9-inch brick can be sawed or even rubbed (by rubbing against an ordinary fire brick) to make them slightly wedge-shaped in order to form tight joints.

Natural diatomaceous brick have considerably higher insulating value when the heat flows perpendicular to the strata or layers, than when it flows parallel to the layers. The brick are sawed from the natural deposits in such a way that the strata are parallel to the $4^1/_2$- by 9-inch faces, hence it is best, from the standpoint of utilization of insulating power, to place these faces flat against the furnace wall. The insulating layer in that case is not self-supporting, but must be held in place by an outer casing of sheet steel or of asbestos lumber, extending from buckstay to buckstay, or by an outer wall of red brick. If, however, the brick are laid the other way, *i.e.*, with the $4^1/_2$- by 9-inch faces horizontal, then the wall is self-supporting if not too high, although even in that case a metal shell is usually provided to prevent injury from moisture or impact. Usually, however, the insulation is given additional stability by bonding with the adjacent refractory brick wall, that is, interlocking the brick. In high-temperature furnaces, however, the difference of expansion of the hot inside wall and the cooler insulating layer may break off the bonding brick or may cause cracks to open. On furnaces which operate continuously for long periods in places where prevention of air infiltration is important (checker chambers and downtakes of open-hearth furnaces, glass tanks) in order to avoid expansion cracks the insulation often is not applied until after the furnace has been brought up to operating temperature. In that case, of course, bonding is impossible.

Recently, insulation was introduced in the form of large blocks, such as 9 by 36 or 12 by 36 inches. The object was to reduce the number of joints, since the latter, in spite of sealing with a mortar, are largely responsible for air infiltration as well as for reduction of insulating value. This commendable innovation has not yet been as widely adopted as it should be. One reason for this is that formerly some of the blocks were furnished only in thicknesses which are multiples of one inch and therefore did not fit in well with standard furnace practice in dimensioning, which is based on multiples of $2^1/_2$ and $4^1/_2$ inches. They are now furnished in many intermediate thicknesses, including $2^1/_2$ inches and $4^1/_2$ inches, and this objection no longer holds. Some furnace builders have had unpleasant experiences with the block insulation, because some of the materials used in the blocks shrank badly when heated and crumbled to powder. The blocks also must be held in place by an outer casing.

Fibrous and granular materials applied to roofs are simply laid in place and tamped down. For

use on side walls, they of course require a stiff casing to hold them in place. Corrugated steel sheets extending from buckstay to buckstay or asbestos lumber may be used, but so far no entirely satisfactory arrangement (with regard to easy access for repairs) has been devised. Air can, of course, filter down between the fibers or grains, hence in this form the insulation is less effective in stopping air infiltration. Both of these disadvantages can be overcome by applying these materials as a plaster. Thus, granulated calcined diatomaceous earth is made into a light concrete with Portland cement; slag wool or granulated slag is mixed with lime, with asbestos, and a small amount of water glass, or with an adhesive clay such as bentonite; expanded mica is mixed with asbestos fibers. The plaster is applied moist, being held in place by nails driven

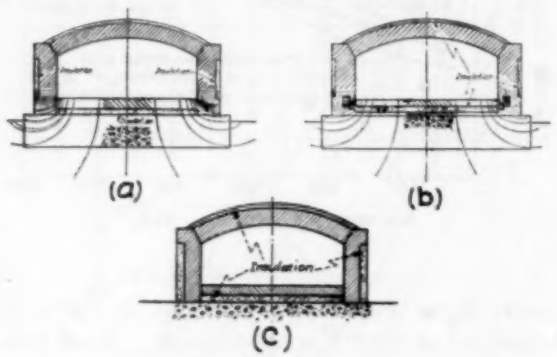


FIG. 2

into the wall here and there. When dried and heated it adheres tightly to the refractory wall, requiring no outer shell and forming a practically air-tight outer surface. Strangely enough, at low temperatures the plaster is a poorer insulator than the loose wool of which it is made, yet it is a better insulator at operating temperatures (Fig. 1). This method of application also permits easy access to the refractories when repairs are needed.

Satisfactory insulation of hearths is difficult. The ordinary panel method of installation (as at (*a*), Fig. 2), from the heat-flow standpoint, is about the poorest possible because there is no insulation at the edges of the hearth or bottom of the side walls, which are just the places where heat flow is much more rapid than elsewhere; in fact, about 32% of the heat lost from a solid hearth is lost through the outer 5% of the width. The insulation is thus located where it can do least good. From the heat-flow standpoint, the insulation should be placed as shown at (*b*), Fig. 2. This type of construction, however, is probably impracticable with the insulating materials now available; besides being subjected to the weight of the side walls, the insulation would, on account of its closeness to the interior at the corners, probably become overheated and also would be especially vulnerable to the attack of slag in furnaces heating iron or steel. Recently the arrangement at (*c*), Fig. 2 has been used. It is a compromise between the requirements of heat saving and those of strength and durability.

The application of insulation to a furnace which is already built is more difficult than its installation while the furnace is being constructed. Except when provision has been made for it in the original design, after-insulation is also more expensive, while the saving which can be effected by it is less. The reason for this is that in high-

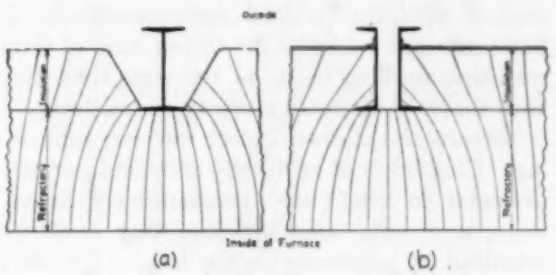


FIG 3.

temperature furnaces the buckstays must be protected from overheating, which means that the insulation must be kept away from them as shown at (*a*) in Fig. 3, unless they are double and have an open space between them (see (*b*), Fig. 3). In either case, parts of the wall are bare or are incompletely insulated, and the lines of heat flow, converging on these places as shown, increase the heat loss as compared to the fully insulated wall.

III. The Use of Refractory Insulators for the Entire Furnace Wall

(1) Development In the first edition of Trinks' Industrial Furnaces, published in 1923, the enormous losses due to storage of heat in the walls of furnaces were for the first time clearly pointed out, and the desirability of having a light-weight refractory insulator or insulating refractory for use not as an outside layer but for the inner lining of furnaces was

emphasized; in the same volume, the relation of high porosity of brick to low thermal conductivity was restated. It is believed that this publication was largely responsible for the initiation by several firms of development work intended to produce insulators which would fulfill these requirements. Of course, insulating brick which could withstand temperatures up to 2200°F had been on the market for years, but these brick, chiefly of the calcined-and-pressed diatomaceous type, were not recommended for use in the interior of furnaces, partly on account of spalling and shrinkage but chiefly because the limiting safe temperature allowed no margin for accidental overheating by impinging flames or currents of hot gases. It is, however, surprising that these materials were so seldom used for the interior walls of resistor-type electric furnaces. The author has used them successfully for that purpose in an experimental furnace, the heating elements at 2000°F being directly in contact with the calcined diatomaceous brick. The latter can easily be cut to any desired form with woodworking tools; at the same time they have the very desirable property of toughness.

The progress of development was very interesting. Clay brick of artificially increased porosity produced in 1927 were comparatively heavy, weak, and soft; after heating, they could be crumbled by squeezing in the hand. By 1930, several makes of clay brick were available having good strength but comparatively low insulating value, the density ranging from 60 to 70 pounds per cubic foot. At this time, diatomaceous brick suitable for temperatures up to 2500°F were produced; again, however, these were not suitable for use inside the furnace. In 1931, two different kinds of insulating brick recommended for this use became available, namely, the kaolin brick and those composed of a mixture of diatomaceous earth with clay. Within the last year, two new makes of porous clay brick have appeared, which have good insulating properties. Silica brick of artificially increased porosity are now available.

The variation in density is also of interest. Low density means good insulating value but also low strength and increased cost. Greater density results in increased strength, but at a sacrifice of insulating value. One make of brick started at 36 pounds per cubic foot, was increased to 53, and recently was reduced to 47. Another started at 33 and recently was increased to 42 pounds per cubic foot. A third, recently introduced at 58, was decreased to 49. Thus the various types are approaching each other. At present, the best compromise seems to result from a density between 42 and 50 pounds per cubic foot.

In view of variations of 2 to 1 in conductivities as determined by various experimenters in tests of the same make of insulating brick (Fig. 4), it is rather risky to state definite values. As an average, however, for the best grades of these brick, the conductivity seems to increase from about 1.8 British thermal units per square foot,

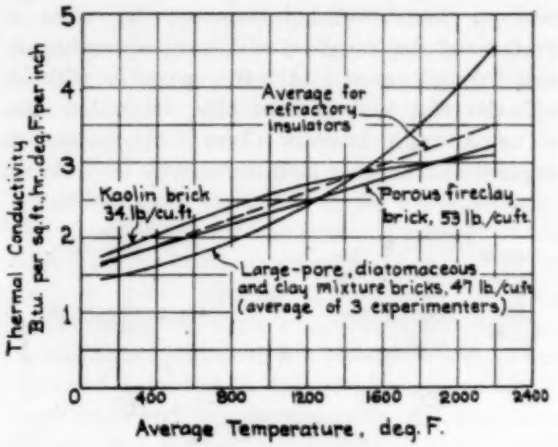


FIG. 4.

hour, degree F per inch thickness at 100°F to about 3.5 at 2200°F in approximately linear relation. This is just about one-third the average conductivity of fire brick. Since the density is also about one-third and the specific heat about equal, the diffusivity is almost exactly the same as for fire brick. This means that, in spite of the much lower conductivity, temperature changes penetrate just as fast within the insulating brick as in the fire brick.

IV. Economics[3]

Since the refractory insulating brick at present cost from two to four times as much as first quality fire brick but have only three times the insulating value of fire brick, at first it appears as if they could show no money saving as to heat conduction alone,[4] since for a given investment in the furnace walls the loss by heat conduction

[3] The question is more fully discussed in the forthcoming 3rd edition of Trinks' Industrial Furnaces.

[4] The fact that the cost of laying is the same for either kind, while the freight charges are greater for the fire brick, results in some reduction of the disparity of cost in the complete installation

would average about the same as for fire brick. If considered on the basis of return on additional investment, however (*i.e.*, use of a greater thickness than would represent the same cost as a given firebrick wall), the refractory insulating brick in many cases show a handsome saving even as to the conduction loss alone. But in such cases a certain saving (perhaps not as great) could be effected also by the use of ordinary insulation outside the fire brick or even by increasing the thickness of the firebrick wall. No reduction of the heat storage losses could be effected, however, by either of the latter courses (in fact, this loss would be increased); whereas the refractory insulating brick, as a result of their light weight, do effect a great saving in the storage loss. It is obvious, therefore, that their outstanding field of use (though by no means their only field) lies in those furnaces in which the loss by heat storage is greater than the heat loss by conduction, that is to say, in intermittently operated furnaces, such as those which are heated up in the morning and shut down overnight or those operated on a heating-and-cooling cycle of fairly short period.

To assist in determining just where the dividing line lies, between the cases in which the use of these materials will pay and those in which it will not pay, the heating-up time, heat storage, and heat conduction losses were calculated for walls of fire brick and for walls of refractory insulating brick, for various furnace temperatures, rates of heat input, and wall thicknesses. The time required for a furnace to be "heated up" is somewhat indefinite, depending largely upon the individual judgment of the furnace operator. Usually, in intermittently operated furnaces, the walls have had time to acquire only a "flash heat" before cold material is charged. The flash-heat time is here defined as the time required for the interior surface of the walls to rise to within 5%

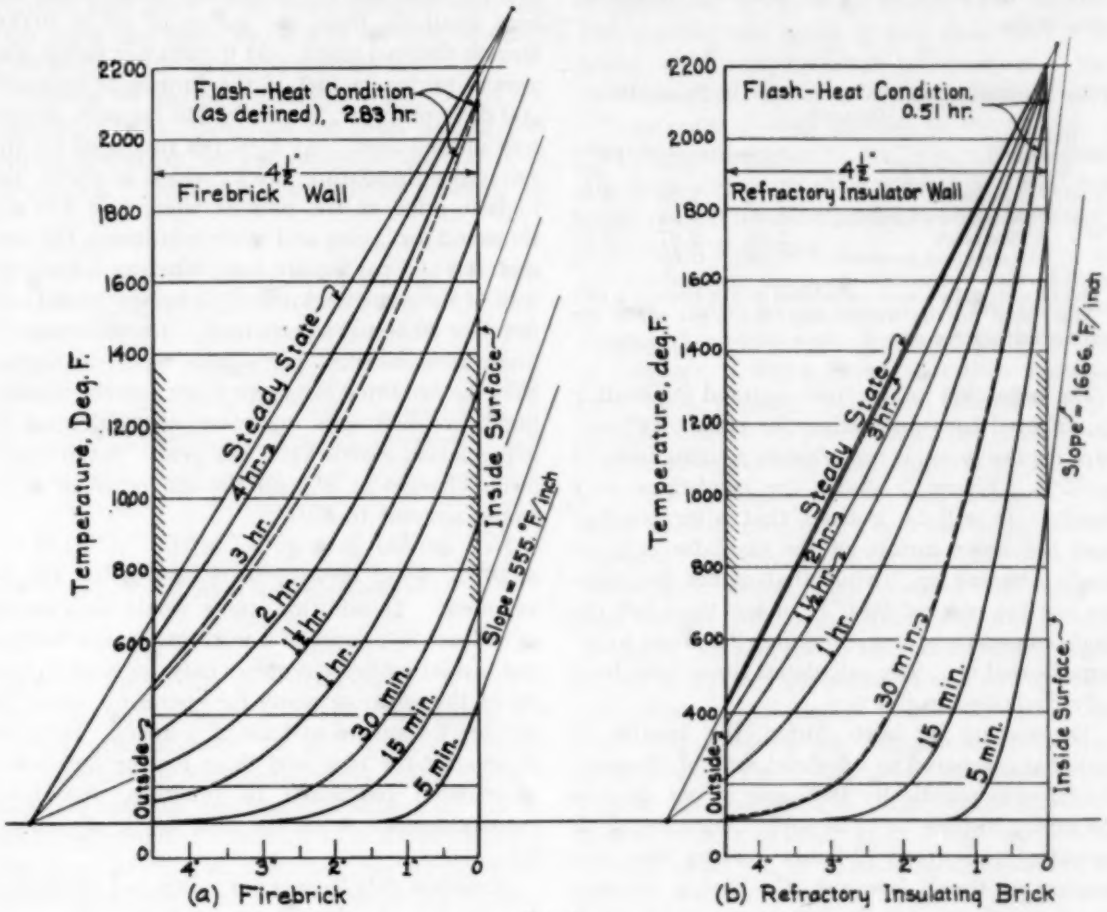


FIG. 5.

of the steady-state temperature. Thus, if 2200°F is the steady-state temperature of the inner surface and if the initial temperature is 100°F, the flash-heat temperature would be 2200 − 5% × (2200 − 100) = 2095°F. This definition is purely arbitrary, but it agrees well with the heating times observed in practice in several types of furnaces. In Table I is shown the heating time in hours for fire brick and for refractory insulating brick walls.

TABLE I

TIME REQUIRED FOR WALLS TO ATTAIN FLASH HEAT (HOURS)

Wall thickness (in.)	Material	Furnace temperature (°F.) 1600	1900	2200
4½	Fire brick	1.72	2.02	2.83
4½	Refractory insulator	0.40	0.44	0.51
9	Fire brick	2.62	2.97	3.32
9	Refractory insulator	0.58	0.63	0.73

The tabular values were calculated on the basis of a rate of heat input to the wall of 5000 B.t.u. per sq. ft. per hour during heating up.

The reduction in the time required for heating up, effected by substituting the refractory insulator for fire brick, is remarkable, ranging from 75 to 82%. Figure 5 shows the conditions very clearly. It will be noticed that after one-half hour the inner surface of the insulator is practically "heated up," while that of the fire brick has not yet reached 1000°F, or less than half the final temperature; and it requires 2.8 hours to become heated up. The calculated times have been fully confirmed in practice.

The saving in heat during the heating-up period as compared to a firebrick wall of the same thickness is practically the same in per cent as the saving in time, or 75 to 85%. Over the whole operating time (6 to 10 hours working time plus heating-up time), however, the saving as compared to a firebrick wall of the same thickness is somewhat less, averaging 67%. On account of heat remaining in the wall overnight, for the 9-inch wall the saving is reduced to 55% for 6-days-a-week operation. The saving in per cent varies only slightly with the furnace temperature; in British thermal units, it is of course the greater, the higher the furnace temperature.

For studying the economics of the use of refractory insulating brick in intermittent furnaces, an oil-fired furnace operating at 2200°F and having 4½-inch thickness of walls will be taken as an example. For eight hours working time, the total heat put into the 4½-inch firebrick wall, including the heat conducted to the outside and heat stored in the brickwork during both the heating-up and the working time, is calculated to be 40,700 British thermal units per square foot of wall area, and into the 4½-inch refractory insulator wall, it is 13,300, a saving of 27,400 British thermal units per square foot. Allowing for the sensible heat in the waste gases leaving the furnace at 2200°F and for some loss by incomplete combustion, the heat available from one gallon of oil is 49,000 British thermal units. At 6 cents per gallon, the annual saving in fuel, if the furnace is operated 300 days per year, is exactly $10 for each square foot of wall area. At $180 per thousand for the refractory insulating brick, which is about the highest price at the present time, and $30 per thousand for laying and other cost items, the first cost is $1.35 per square foot, whereas a firebrick wall of the same thickness (4½ inches) would cost not over $0.48 per square foot. The difference in investment is $0.87 per square foot. Assuming that the fire brick lasts two years and the insulating brick wall only one year, the difference in depreciation cost is $1.11 per year. Interest and other charges at 8% on the difference of $0.87 would amount to $0.07.

Net annual saving = $10.00 − $1.11 − $0.07 = $8.82 or over 900% return on the investment. In addition, there would be a saving of at least 2¼ hours of a workman's time because the insulating brick requires only ½ hour to heat up in the morning ready for operating, while the fire brick requires at least 2¾ hours. Both the figures for the time and those for the fuel saving have been confirmed in practice. For lower furnace temperatures, the heat saving of course is less.

If oil cost only 2 cents per gallon and the furnace were operated only 100 days per year, the saving (assuming depreciation to be proportional to the number of days actually operated) would still be $0.64 or a return of 66% on the additional investment in the insulating brick. Hence it is evident that even with cheap fuels and when plant operation is at a low rate, the refractory insulators will show good savings, provided, of course, the brick lining has a reasonable length of life.

In furnaces operated continuously on heating-and-cooling cycles (annealing furnaces, large forge furnaces), the case is somewhat different, because in these, the refractory insulator wall would not replace a firebrick wall of the same thickness but

one of considerably greater thickness; for example, a wall of 18-inch fire brick plus 2½ inches of ordinary insulation would usually be replaced by a 9-inch insulating refractory wall. The saving is less than figured above but still represents an excellent return on the investment in most cases.

The general conclusion to be drawn from these calculations is that in practically every intermittently operated furnace where these brick can be used they show remarkably good savings, but that great care must be used in deciding whether they are suitable for use in a given case.

Figures for savings effected by the use of the insulating brick, based on the total cost of fuel during operation, can not always be taken at their face value. Thus, in a brass-heating furnace, the

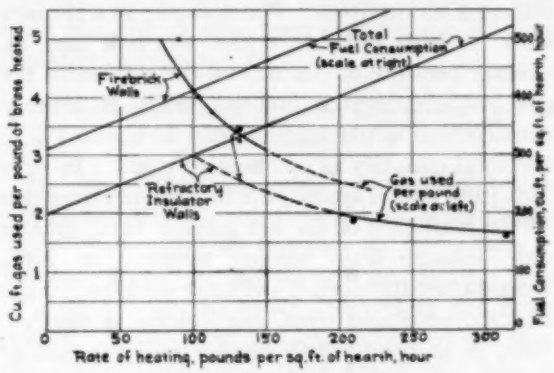


FIG. 6.

apparent fuel saving was about 50%. When the fuel-consumption figures were plotted against the heating rate, however, as in Fig. 6, it became evident from the form of the curve that if the rate at which material was heated had been as high in the furnace built of fire brick as in the one built of insulating brick, the difference in fuel economy would have been much less. The saving attributable to the insulating brick was not over 20%, the additional reduction of fuel consumption per pound being due to the increased heating rate.

The above figures are all based on the assumption that the refractory insulating brick will have a reasonable length of life. If they have not, the replacement cost will soon eat up the saving. Not enough information is as yet available to permit passing judgment on this point. The greatest factor in shortening the life of the furnace walls usually is spalling. The makers of the refractory insulators claim that these brick do not spall more than fire brick; on the other hand, the writer's observation as well as that of well-known builders of furnaces allows the general statement to be made that, except at quite low temperatures, the spalling is greater than that of fire brick. It is, however, as yet impossible to give any figures on the relative length of life in actual furnaces.

In the research laboratory of the Electric Furnace Company at Salem, Ohio, panel spalling tests were made on four of the best-known makes of insulating brick, both coated and uncoated. The spalling was much greater than that of fire brick, and occurred in a characteristic way. Cracks started at the surface and went inward at 45°, meeting a crack parallel to the surface, so that the surface layer ¼ to ½ inch thick fell off. The tests seemed to show conclusively that none of the present insulating brick is suitable for use in combustion chambers.

At this point, the great question, "to coat or not to coat," must be mentioned. When the newly developed insulators were first used for the interior of furnaces, it was believed that these materials could not possibly withstand the destructive influences unless they were protected in some way. The first method used was to apply a ½-inch layer of furnace cement to the inner surface. This layer was expected to act as a buffer or "thermal flywheel," smoothing out excessive fluctuations of temperature before they reached the insulator, and thereby reducing spalling; it was also intended to act as a shield against impinging flames as well as against the action of slag and abrasion; and most important, it sealed the pores and prevented penetration of hot gases into the body of the brick. The ½-inch layer, of course, did not adhere but cracked off. After various trials, a thinner coating of finely ground high-temperature cement, about 1/16 to ⅛ inch thick, applied to the interior wall surfaces was found to adhere well. (In fact, the bond is stronger than the brick.) Some users, however, were bold enough to try the brick without any protective coating and they found that in some cases the results were entirely satisfactory. Thus there are the two schools of opinion: those who hold that a protective coating should be used and those who believe that it is unnecessary. Even the makers of the brick do not as yet know which is correct. All that can be said at present is that the coating is desirable for high-temperature work.

The effects of the greater permeability of the insulating brick must be considered. As far as

the effect on thermal conductivity is concerned, in the author's opinion this is not of great importance for the following reasons. The amount of heat transferred through the wall is reduced by inward air flow when a draft exists in the furnace and is increased by outward flow of hot gases in the more usual case when a pressure exists. The apparent conductivity becomes

$$C_a = C \pm Vqc_p s$$

where C = true conductivity (B.t.u./sq. ft., hr., °F/in.)
V = quantity of gases seeping through brick, in cu. ft./hr. and sq. ft. wall area
q = density of the gases in lb./cu. ft.
c_p = specific heat
s = thickness of wall (in.).

NOTE: This equation is based on the assumption that the gases as they pass through the brick, have at every point the same temperature as the material of the brick at that point (after equilibrium has been attained). For the gases passing through the pores of the brick, the heat transfer in the narrow tortuous passages is so active that the assumption is certainly correct. For the gases passing through the joints it is approximately correct, provided the gaps are not too wide.

The minus sign applies in the case of air infiltration, the plus sign in the case of outward leakage of gases. The quantity, V, varies with the pressure in the furnace and with the permeability of the brick, including the joints.

Calculating on the basis of Bansen's test,[5] when the furnace pressure is $^1/_{40}$ inch of water in a 2200° furnace with 9-inch walls, the apparent conductivity of fire brick would, on the average, be increased about 6%. For the insulating brick, even if they had no greater permeability, the increase would be 18%. It looks at first, then, considering the greater permeability, as if the heat loss would mount up to a large item. At the time this paper was being prepared, few data on permeability of refractory insulating brick were available. One test made by Easter[6] showed that porous clay brick have about $2^1/_2$ times the permeability of ordinary fire brick. It must be remembered, however, that in a firebrick wall, most of the leakage is through the joints: according to Bansen, it amounts in the average wall to about 94%, while the leakage through the pores of the fire brick themselves is only about 6% of the total. If the latter were increased $2^1/_2$ times, the total would be only 9% greater in the insulating brick wall, and the resulting apparent increase of conductivity of the insulating brick would be $19^1/_2$%.

[5] *Arch. Eisenhüttenwesen*, **1**, 687 (1927–28).
[6] G. J. Easter, *Jour. Amer. Ceram. Soc.*, **11** [10], 764 (1928).

This, however, in most furnaces does not represent an increased loss of heat, because the gases would leave at furnace temperature in any event, carrying with them a definite amount of sensible heat regardless of whether they leave through the flues and vents or whether part of the gases seeps out through the brick walls. Actually the true conduction loss is slightly *reduced* by outward leakage because the temperature gradient in the wall is reduced. In the majority of cases, therefore, leakage through the walls can be neglected as far as heat loss is concerned.

Gas leakage, however, at the high-temperature end of continuous furnaces does represent a real loss also in any furnace equipped with a recuperator or other heat-saving device.

In actual amount, the loss of gases by seepage is seldom a serious item. For example, in a furnace with $^1/_{20}$-inch pressure under the roof and an average pressure of $^1/_{40}$ inch on the side walls, the gas leakage through firebrick walls of average construction would amount only to about 2% of the total quantity of combustion gases. In very high furnaces, of course, the internal pressure due to the buoyancy of the hot gases is much greater and leakage may become serious. In high-temperature furnaces, if the inner surfaces become sintered or glazed over, gas leakage is reduced; thus, in an open-hearth furnace roof the outside temperature of the roof was 680°F soon after starting up, but after the roof had become glazed it dropped to 590°F because the gas leakage stopped.

While unimportant as to heat loss, gas leakage has other disadvantages: it sends out additional heat and noxious gases into the furnace room to the detriment of the workmen and it causes deterioration of the brick by carrying into the pores dust, carbon, and fluxes. The carbon monoxide also attacks certain constituents of the brick at quite low temperatures. The use of a coating of high-temperature cement on the inside surfaces practically stops the gas leakage.

Some furnace builders still hesitate to construct the roofs of refractory insulating brick except for short spans because they fear that shrinkage will allow the arch to collapse. The better kinds of these brick, however, do not shrink to any extent below 2500°F and for most furnaces should therefore be perfectly safe. For low temperatures, arches of 15-foot span made of these brick have given satisfaction. In sheet fur[illegible] in

some cases trouble is said to have resulted from a slight crumbling or detachment of small pieces from the lower surface of the arch. The particles dropping on the sheets were sufficient to mar the surface.

The use of these brick for the upper layers of hearths is practically out of the question in most cases because they can not resist abrasion or slag penetration and they lack mechanical strength. This limitation is becoming of less importance as more and more furnaces are built of the conveyer-hearth types. One make of porous clay brick, with a density of 60 pounds per cubic foot, shows satisfactory resistance to abrasion because it has the original outer surface as fired. (In most of the other insulating brick, this outer skin is removed when they are ground to size.) The brick referred to have been used for the bottoms of car-type furnaces.

V. Obstacles Which Prevent the Wider Use of Insulation

In view of the remarkably good savings which are figured as obtainable from the use of insulation in most cases, whether it is used for the outside or for the entire furnace wall, it seems strange that the practice of insulating furnaces is not more general. Aside from the limitations which have already been explained, there are several reasons for this.

Probably the most important is cost. Insulation does add to the first cost of a furnace and many buyers therefore refuse to consider it. One furnace sales-engineer states that when he goes into a plant preparatory to making a proposal for installing a furnace, he sizes up the appearance of the plant and the character of the management. If the plant is well kept with evident and intelligent attention to details and if those in charge are technically trained men, the bidder figures on using a good thickness of insulation; if, on the contrary, the appearance of the plant shows that little attention is paid to economy and the men in charge are of the rough-and-ready type chiefly interested in getting out the work and impatient of technical details, then the furnace salesman omits insulation because he knows that the lowest-cost furnace will be ordered. This being the existing condition, the reason why there is no "standard practice" in insulating furnaces is evident.

Another reason is the rather poor insulating quality of even the best insulators. A good insulator should practically stop heat loss, whereas the insulating materials at present available reduce the loss by only about two-thirds. This need not always be so: it is conceivable that an insulating layer, metal jacketed, evacuated, and containing many layers of shiny metallic foil or other reflecting particles in a sufficiently fine state of subdivision (in the direction of heat flow) could be developed, which would be an even more effective insulator at high temperatures than is the thermos bottle at low temperatures and which would allow the escape of perhaps only 1% as much heat as present insulators. The trouble then would be to find a sufficiently heat-resistant metal for the inner wall of the casing. Or, when physicists learn more about the internal actions by which heat conduction is effected, means may possibly be found to reduce radically or practically to stop the heat flow through solids such as refractories.

Replacement cost is another objection to the use of insulation. Thus, in many open-hearth furnaces, at the end of a campaign the roof is simply knocked in and the debris (silica brick and insulation) is shoveled out or taken out with a grab bucket or with the charging machine. Any attempt to salvage the insulation would result in high labor cost. The steel plant people, for that reason, often prefer to use home-made insulating materials like slag wool, which being by-products are inexpensive and result in little loss if not salvaged.

Other objections are (1) interference with quick repairs when insulation is used, particularly if it is held in an outer casing, (2) uncertainty as to the effect on the life of refractories, (3) necessity for more careful operation, as in an open-hearth roof, where inattention for a very brief period may result in melting down the roof, if insulated, (4) production of powder or dust, which in glass plants for example can not be tolerated, (5) quicker clogging of checkers, due to shutting off the air infiltration with resulting change of temperature conditions.

Each installation, therefore, presents problems of its own with the use of insulation.

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ON SOME NEW GLASSES CONTAINING BISMUTH*

By E. Raymond Riegel† and Donald Sharp‡

ABSTRACT

Meltings were made of several soda-bismuth-silica and potash-bismuth-silica glasses. Data are given on refractive index, mean dispersion, and specific gravity. In general, the refractive index, specific gravity, and durability of bismuth glasses are higher than those of the corresponding lead glasses.

I. Antimony versus Bismuth in Glass

There are only a limited number of glasses suitable for the reduction of the secondary spectrum in lenses. Of these, the borate flints, although valuable from the standpoint of optical properties, are so lacking in permanency that they can not be used except under special conditions. The so-called "telescope flint" is a glass somewhat similar in composition to a borate flint of low refractive index but in which the lead oxide is replaced by antimony oxide. Probably the contribution of the antimony to the peculiar dispersion of the telescope flint is not much different from that which would be produced by lead. The important point is that the antimony glass is more resistant to atmospheric attack, or weathering, than the corresponding glass containing lead.

It was evident from some experiments by one of the authors that antimony could not be utilized in a glass to a greater extent than about 20%. The difficulties are several: (1) the antimony volatilizes, (2) it makes soft glasses, and (3) if it is used in large quantities the glasses become appreciably colored. However, if it were possible, it would be desirable to employ much larger quantities of antimony in the glass. The higher antimony content would produce a higher refractive index and a lower V.[1] Although telescope flint is the only commercially practical flint glass which really contributes to the reduction of secondary spectrum, its more general use is prevented by the fact that its refractive index is about the same as that of spectacle crown and its V only about 5 units lower.

It was thought that bismuth might impart much the same properties as antimony and that it might be possible not only to incorporate much more bismuth in the glass, but that the glasses containing higher amounts of bismuth might be quite stable. As a first step in the problem it was decided to investigate the optical properties of the soda-bismuth-silica and potash-bismuth-silica glasses and to ascertain if there were any pecularities in these simple compositions before proceeding to more complex glasses.

According to Fuwa[2] bismuth does not yield satisfactory glasses. His results indicate that bismuth not only imparts a gray color to glass but that the glasses devitrify easily. The results of the writers definitely show that bismuth can be incorporated in glass to the extent of more than 50%. Moreover, it is concluded that the gray color experienced by Fuwa probably could be traced to the presence of a reducing agent. The addition of a small amount of arsenic, along with an oxidizing agent, prevents any tendency toward development of a gray color.

II. Preparation of the Glasses

The glasses in the series first investigated were of the general molecular formula $100SiO_2$, 40 Na_2O, xBi_2O_3, where x was approximately $2\frac{1}{2}$, 5, $7\frac{1}{2}$, 10, 15, and 20 in the different glasses. This series was chosen in order that it might be compared readily with Peddle's[3] first series of soda-lead glasses.

Bismuth was introduced as trioxide[4] which was of a particularly good grade for a commercial material. A considerable quantity of the sodium was introduced as nitrate to guard against reduction of the bismuth oxide to metallic bismuth. The raw materials were of good grade and all were analyzed. A small amount of arsenic trioxide was added to each melt.

If there were no pot attack or volatilization from the batch (except water and gas) the glasses

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[1] The quantity, V, sometimes termed the "constringence," is the ratio of the relative refractivity to the mean dispersion. It is defined by $\frac{n_D - 1}{n_F - n_C}$.

[2] K. Fuwa, *Jour. Jap. Ceram. Assn.*, **32**, 5 (1924).

[3] C. J. Peddle, *Jour. Soc. Glass Tech.*, **4**, 299 (1920).

[4] Furnished through the courtesy of the American Smelting, Refining & Mining Company.

when melted would have had the percentage composition given in Table I.

TABLE I

	SiO_2 (%)	Na_2O (%)	Bi_2O_3 (%)
35B	64.83	22.86	12.31
40B	57.71	20.36	21.93
45B	52.01	18.35	29.64
50B	47.33	16.70	35.97
60B	40.12	14.15	45.73
70B	34.81	12.28	52.91

At first meltings were made in batches weighing about 100 grams each. Later meltings about four times this size were made, so that more homogeneous pieces would be available for the various tests. A small Fletcher furnace, fired with natural gas, was used for melting. The ordinary refiners' crucibles were employed except in the case of glasses containing over 30% of bismuth, for which special crucibles were required.

The materials were melted from two to three hours at a temperature of about 1300°C. In most cases the melts were stirred by means of a porcelain rod in order to obtain better homogeneity. The batches melted quite readily, yielding clear glasses containing some bubbles and considerable striae. Glasses 50B, 60B, and 70B frothed rather violently at first. It was noted also that the bismuth oxide was volatilized somewhat from glass 70B because the oxide condensed on the cooler portions of the outside of the furnace lid. Nevertheless, as will be pointed out later, the analyses indicated that the loss of bismuth was not of serious moment in any of the glasses.

After each melt had progressed sufficiently, the crucible was removed from the furnace, covered with Sil-O-Cel powder, and allowed to cool. After the glass had cooled it was chipped out and the pieces freed from any portions of the crucible. Those portions of the glass which were quite evidently near the crucible or the surface of the glass were rejected. All the glasses were clear and there was no evidence whatever of crystallization or devitrification. The glasses were unchanged by being heated to the softening point in subsequent annealing. A summary of the appearance of each glass is given in Table II.

TABLE II

Glass No.	
35B	Colorless, transparent, few bubbles, slight lack of surface luster.
40B	Nearly colorless, transparent, very few bubbles, slightly dull surface.
50B	Light yellowish green tint, transparent, rather few bubbles, brilliant surface.
60B	Yellow tint, transparent, quite bubbly, very brilliant surface.
70B	Definite yellow color, transparent, quite bubbly, very brilliant surface which tarnished after some months' time.

When melted on a larger scale, the glasses were essentially the same color as were the smaller melts. All of the larger melts were more free from bubbles than the glasses made on a smaller scale, and all were very brilliant in appearance.

III. Analyses of the Glasses

In any correlation of physical properties of glasses with chemical composition, it is important that the compositions be obtained by analyses of the glasses rather than by calculation from the batch. Various methods of analysis were tried on the bismuth glasses, in some instances with disastrous results to platinum ware.

In view of the fact that the bismuth and alkali contents were most important, these only were finally determined in most of the glasses. This permitted solution of the glasses in hydrofluoric acid and simplified matters greatly. Enough checks were made by different methods to ensure accuracy and absence of appreciable effect of pot corrosion. From two to five determinations were made in each case. The mean results are given in Table III.

TABLE III

Glass No.	Bi_2O_3 (introduced)	Bi_2O_3 (found)	Na_2O (introduced)	Na_2O (found)
(Analyses of 100-Gram Melts for Bismuth and Sodium)				
35B1	12.31	12.71	22.86	24.30
40B1	21.93	20.67	20.36	22.73
45B1	29.64	29.52	18.35	20.83
50B1	35.97	34.34	16.70	18.23
60B1	45.73	45.75	14.15	14.48
70B1	52.91	52.87	12.28	13.55
(Analyses of 400-Gram Melts)				
35B2	12.31	12.40	22.86	23.78
40B2	21.93	22.00	20.36	21.87
45B2	29.64	29.66	18.35	19.18
50B2	35.97	34.51	16.70	14.99
60B2	45.73	44.92	14.15	14.24

IV. Optical Properties and Specific Gravity

Determinations of specific gravity were made by the immersion method and by a pycnometer. Corrections were made for temperature of the distilled water, and the specimens were the same plates or prisms employed later for measurements of optical properties. A summary of the results is given in Table IV.

Optical properties were determined on the Abbé and Pulfrich refractometers and also in some

TABLE IV

Refractive Index (n_D) and Specific Gravity of Soda-Bismuth Glasses. Series $100SiO_2$, $40Na_2O$, xBi_2O_3

Glass No.	Bi_2O_3 (%)	Specific gravity	n_D	n	V
35B2	12.4	2.7166	1.5352	0.01119	47.8
35B1	12.7	2.725	1.535		
40B1	20.7	2.941	1.565		
40B2	22.0	2.9561	1.5697	0.01333	42.7
45B1	29.5	3.171	1.600		
45B2	29.7	3.1801	1.5948	0.01546	38.5
50B1	34.3	3.333	1.624		
50B2	34.5	3.3699	1.6109	0.01673	36.5
60B2	44.9	3.7629	1.6668	0.02114	31.5
60B1	45.8	3.73	1.670		
70B1	52.9	4.110	1.712		

(The data given to three decimal places were obtained on the samples from the smaller melts which were less homogeneous than the samples from the larger ones.)

cases on a Spencer precision spectrometer in the research laboratory of the Spencer Lens Company of Buffalo, N. Y. Mean results for n_D by the

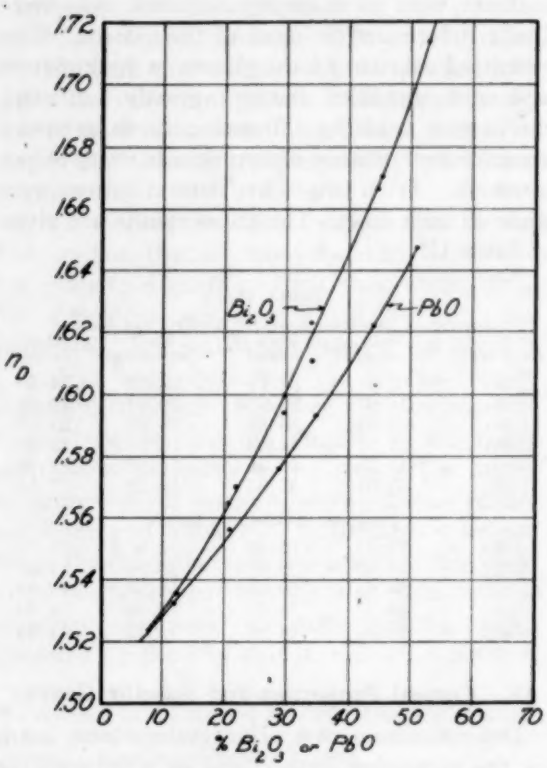

FIG. 1.—Refractive index, n_D, of glasses series $100SiO_2$, $40Na_2O$, x PbO or Bi_2O_3.

various methods on specimens from the several meltings are also given in Table IV as well as the mean dispersion Δn and V value (constringence).

V. Comparison with Corresponding Lead Glasses

It will be noted in Fig. 1 that bismuth oxide, on a basis of percentage by weight, gives a higher refractive index than the corresponding glass with lead oxide. The density curves in Fig. 2 show, similarly, that the bismuth glasses are more dense than corresponding lead glasses.

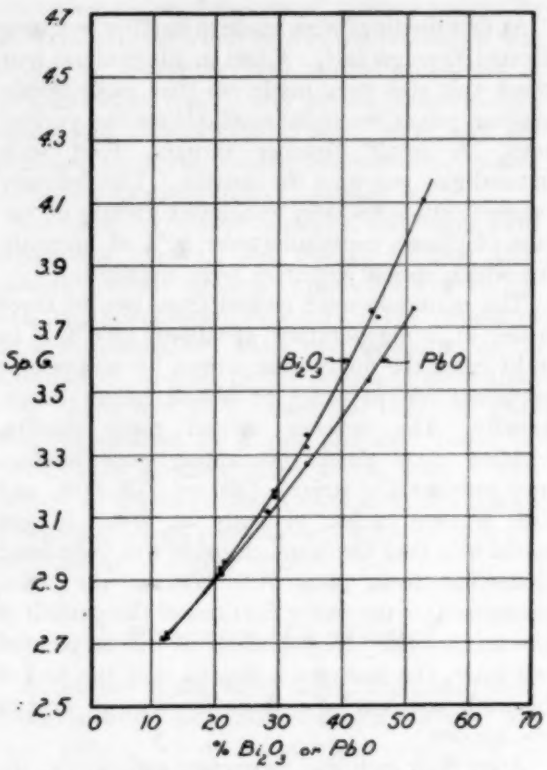

FIG. 2.—Specific gravity of glasses series $100SiO_2$, $40Na_2O$, xPbO or Bi_2O_3.

Accurate measurements of dispersion on several of the glasses were rendered impossible due to the amount of striae present. However, from the writers' experience with glasses of normal composition melted on a small scale it could not be concluded that the bismuth glasses were more likely to be striated than lead glasses. Such measurements as were felt to be trustworthy were accepted and on the others no measurements are reported. It is a matter of wonder how Peddle succeeded in obtaining trustworthy measurements of dispersion on the great variety of glasses he melted on a small scale.

Figure 3 indicates the variation of mean dispersion with the refractive index. The solid line

represents the bismuth glasses and the dotted line is from Peddle's data on the lead glasses, series $100SiO_2$, $40Na_2O$, xPbO. It is to be noted that the mean dispersions are practically identical in bismuth and lead glasses of the same refractive index.

VI. Durability Tests

There is no test of weathering power which is absolutely conclusive except the actual exposure of the glass to atmospheric conditions over a long

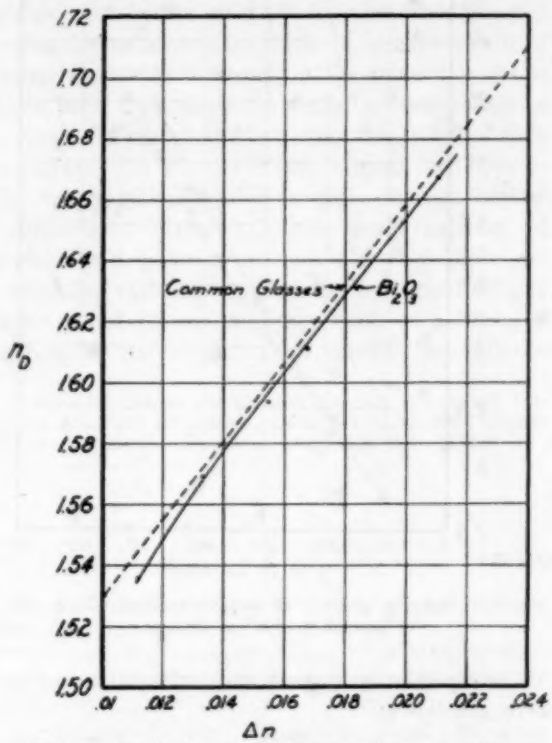

FIG. 3.—Variation of mean dispersion, Δn, with refractive index n_D, in standard optical glasses and in bismuth glasses type $100SiO_2$, $40Na_2O$, x Bi_2O_3.

period of time. Nevertheless, in order to gather some data on this point even though it might not be conclusive, tests were made by a method similar to that employed by Peddle[5] on soda-lead glasses. The method in brief is as follows:

The glass is ground to a powder. That portion which will pass through a 150-mesh sieve and be retained by a 200-mesh sieve is utilized for the test. A known weight of this material is digested in water at 80°C for one hour and the liquid decanted off; the residue is washed with alcohol, filtered, and added to the main part of the liquid. This is then titrated with acid using phenolphthalein as an indicator.

As was to be expected, the amount of alkali liberated decreased progressively with decreasing alkali content of the glasses. The results obtained on a few of the glasses are given in Table V. More detailed data on durability will be given in a subsequent paper after tests have been completed on samples of semicommercial meltings.

VII. Comparisons of Solubilities of Bismuth and Lead Glasses

A comparison of the solubilities of the bismuth glasses with the corresponding glasses containing

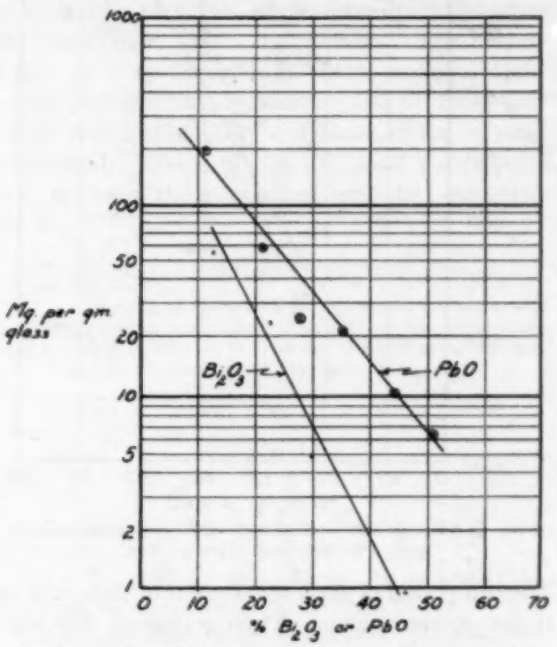

FIG. 4.—"Solubility" of bismuth and lead glasses by Peddle's method.

lead is given in Fig. 4. Semilogarithmic paper was used in making these curves, the percentage of bismuth or lead being on the horizontal or equal parts scale, with "solubility," that is, the weight of alkali liberated, on the logarithmic scale. It is to be noted that the bismuth glasses seem to be

TABLE V

(Milligrams Alkali Liberated per Gram Glass)

Glass No.	5 G. glass in 100 cc. water	Bi_2O_3 (%)
35B	55.9	12.31
40B	24.2	21.93
45B	4.9	29.64
50B	3.4	35.97
60B	0.95	45.73

A sample of soft soda glass tubing, as commonly used in the laboratory, gave 2.64 milligrams alkali per gram of glass.

[5] C. J. Peddle, *loc. cit.*

less soluble than the corresponding glasses throughout the entire range covered.

VIII. Potash-Bismuth-Silica Glasses

Some investigation was also made of bismuth glasses in which the alkali was all introduced as potash in the series $100SiO_2$, $40K_2O$, xBi_2O_3.

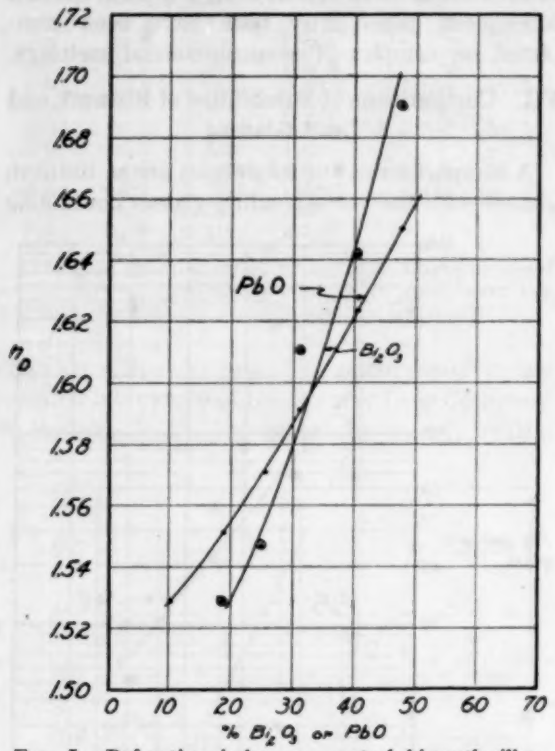

FIG. 5.—Refractive index, n_D, potash-bismuth-silica and of potash-lead-silica glasses.

About a pound of glass was melted in each case as in the previous series. There was some difficulty with crystallization. Data on a few of the glasses are listed in Table VI.

TABLE VI

REFRACTIVE INDEX AND SPECIFIC GRAVITY OF POTASH-BISMUTH GLASSES

Glass No.	Specific gravity	n_D	Bi_2O_3 calculated from batch (%)
1K	2.6072		10.25
2K	2.8236	1.5295	18.58
3K	3.0506	1.5470	25.50
4K	3.2638	1.6110	31.35
5K	3.5843	1.6420	40.66
6K	3.8842	1.6915	47.72

In Figs. 5 and 6 are given comparisons of the refractive index and specific gravity of the potash-bismuth glasses with the corresponding potash-lead glasses.

IX. Bismuth-Antimony Glasses

As the next step in the study of "telescope" flint glass, the three following glasses were prepared on a small scale.

	No. 1-S (%)	2-S (%)	3-S (%)
SiO_2	49.5	39.6	29.7
B_2O_3	20.1	20.1	20.1
Bi_2O_3	22.4	22.4	22.4
Na_2O	2.2	2.2	2.2
K_2O	4.4	4.4	4.4
Al_2O_3	1.4	1.4	1.4
Sb_2O_3	None	9.9	19.8

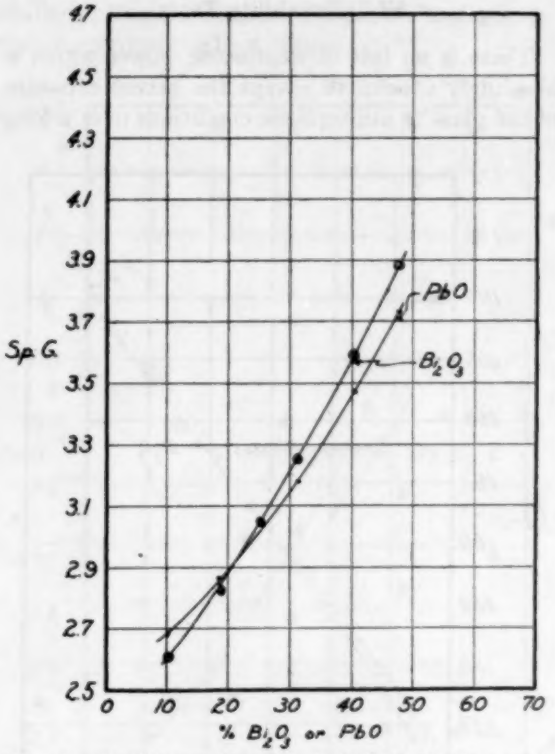

FIG. 6.—Specific gravity of potash-bismuth-silica and of potash-lead-silica glasses.

The specific gravities and refractive indices were as follows:

Glass No.	Specific gravity	n_D
1-S	2.749	1.5378
2-S	2.924	1.5718
3-S	3.134	1.6070

Difficulty was encountered with dispersion measurements because of the cordiness of the glass. Accordingly, it was decided to make additional melts under conditions which would reduce pot attack, permit better stirring of the glass, and thereby obtain more homogeneous samples. The results of the study of these glasses will be presented in a subsequent paper.

Acknowledgment Acknowledgment is due Kenneth MacAlpine who carried out a great share of the measurements and tests quoted herein, as a part contribution toward the requirements for a Master's Degree at the University of Buffalo, also to John Richelsen, Jr., who performed part of the solubility work.

FACTORS FOR THE CALCULATION OF CERAMIC AND NONMETALLIC MINERALS*

By Kenneth G. Skinner and Hewitt Wilson

ABSTRACT

A table of ratios between the oxide components of ceramic and nonmetallic minerals was devised for slide-rule calculations and can be used for calculation between the compound and its equivalent oxide. Examples of the two methods of calculation are given at the back of the table.

The use of weight ratios of the oxides in ceramic glazes and bodies in place of the time-honored molecular ratios has been handicapped for four or more reasons as follows: (1) the molecular ratios have been used since the technical beginnings of ceramic chemistry and our literature is full of such examples; (2) many ceramists think in terms of the empirical molecular formula instead of the oxide-weight ratios; (3) the usual method of molecular calculation uses simple whole number-combining ratios instead of the fractional weight ratios; and (4) no facilities, such as a table of factors for the weight ratios, have been available for general use. Staley[1] has long been an advocate of the oxide-weight ratios. The U.S. Bureau of Standards uses both methods. The Geophysical Laboratory, while using molecular formula for the expression of theoretically pure compounds, uses *weight per cent* for all combinations of these compounds.[2]

The tables have been devised for slide-rule calculation and two operations are saved in each calculation, namely, transfer of weight ratios to molecular ratios and the reverse operation after the molecular oxide distribution. The superscript "*a*"[3] in the table indicates an equivalent oxide form obtained by heating and oxidizing and which is not necessarily contained in the original compound. The ratios can be used for calculation between the compound and its equivalent oxide.

* Read by title at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (White Wares Division). Received December 29, 1933.

[1] See references 16 and 17 in Bibliography.

[2] See reference 7.

[3] The molecular weights with superscript *a* are not arithmetical "ceramic equivalent weights" of the compound from which it is derived in the case of a change of valence or a change in the number of molecules.

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Name	Formula	Constituents	Weight	Per cent	Ratio			
Akermanite	$2CaO \cdot MgO \cdot 2SiO_2$	CaO	112.2	41.2	1.000	2.78	0.936	
		MgO	40.3	14.8	0.359	1.00	0.336	
		SiO_2	120.2	44.0	1.068	2.97	1.000	
			272.7	100.0	2.427	6.75	2.272	
Albite. *See Soda feldspar.*								
Allophane	$Al_2O_3 \cdot SiO_2 \cdot 5H_2O$	Al_2O_3	101.9	40.4	1.000	1.690	1.132	
	$Al_2SiO_5 \cdot 5H_2O$	SiO_2	60.1	23.9	0.592	1.000	0.672	
		H_2O	90.0	35.7	0.884	1.494	1.000	
			252.0	100.0	2.476	4.184	2.804	
Alum, ammonium	$Al_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$	Al_2O_3	101.9	11.2	1.000	2.988	0.318	0.2260
	$Al_2O_3 \cdot 2NH_3 \cdot 4SO_3 \cdot 25H_2O$	NH_3	34.1	3.8	0.335	1.000	0.106	0.0677
		SO_3	320.4	35.3	3.144	9.395	1.000	0.7125
		H_2O	450.0	49.7	4.416	13.190	1.404	1.0000
			906.4	100.0	8.895	26.573	2.828	2.0062
Alum, potash	$Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	Al_2O_3	101.9	10.8	1.000	1.082	0.318	0.236
(Kalinite)	$Al_2O_3 \cdot 2K_2O \cdot 4SO_3 \cdot 24H_2O$	K_2O	94.2	9.9	0.923	1.000	0.294	0.218
		SO_3	320.4	33.8	3.145	3.405	1.000	0.742
		H_2O	432.0	45.5	4.219	4.580	1.345	1.000
			948.5	100.0	9.287	10.067	2.957	2.196
Alum, soda. *See Mendozite, natroalunite.*								
Alumina (corundum)	Al_2O_3	Al_2O_3	101.9	100.0				
Aluminum-ammonium sulfate. *See Alum, ammonia.*								
Aluminum-boron silicate. *See Dumortierite.*								
Aluminum-potassium sulfate. *See Alum, potash.*								
Aluminum hydroxide	$Al_2O_3 \cdot 3H_2O$	Al_2O_3	101.9	65.4	1.000	1.885		
(Aluminum hydrate)		H_2O	54.0	34.6	0.530	1.000		
			155.9	100.0	1.530	2.885		
Aluminum oxide. *See Alumina.*								
Aluminum silicate								
See Andalusite (cyanite, fibrolite, sillimanite)	$Al_2O_3 \cdot SiO_2$							
See Allophane.	$Al_2O_3 \cdot SiO_2 \cdot 5H_2O$							
See Rectorite.	$Al_2O_3 \cdot 2SiO_2 \cdot H_2O$							
See Kaolinite (dickite, nacrite, clay).	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$							
See Newtonite.	$Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$							
See Halloysite (Indianaite)	$Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$							
See Pyrophyllite.	$Al_2O_3 \cdot 4SiO_2 \cdot H_2O$							
See Montmorillanite.	$Al_2O_3 \cdot 4SiO_2 \cdot 6H_2O$							
See Collyrite.	$2Al_2O_3 \cdot SiO_2 \cdot 9H_2O$							
See Pholerite (Guillemin)	$2Al_2O_3 \cdot 3SiO_2 \cdot nH_2O$							
See Cimolite.	$2Al_2O_3 \cdot 9SiO_2 \cdot 6H_2O$							
See Mullite.	$3Al_2O_3 \cdot 2SiO_2$							
Alunite	$K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$	K_2O	94.2	11.4	1.00	0.308	0.295	0.872
	$KAl_3O_8H_6S_2O_3$	Al_2O_3	305.7	37.0	3.25	1.000	0.958	2.830
		SO_3	320.2	38.6	3.39	1.044	1.000	2.965
		H_2O	108.0	13.0	1.14	0.351	0.337	1.000
			828.1	100.0	8.78	2.703	2.590	7.667
Andalusite	$Al_2O_3 \cdot SiO_2$	Al_2O_3	101.9	62.9	1.000	1.690		
		SiO_2	60.1	37.1	0.590	1.000		
			162.0	100.0	1.590	2.690		
Anglesite. *See Lead sulfate.*								
Anhydrite	$CaSO_4$	CaO	56.1	41.2	1.00	0.700		
	$CaO \cdot SO_3$	SO_3	80.1	58.8	1.43	1.000		
			136.2	100.0	2.43	1.700		
Anorthite. *See Calcic feldspar.*								
Antimony oxide	Sb_2O_3	Sb_2O_3	291.5	100.0	1.000	0.947	0.901	
(Senarmonite)	Sb_2O_4	Sb_2O_4	307.5	100.0	1.055	1.000	0.951	
(Valentinite)	Sb_2O_3	Sb_2O_3	323.5	100.0	1.100	1.052	1.000	
Apatite	$10CaO \cdot 2F \cdot 3P_2O_5$	CaO	561	54.7	1.000	1.315	14.80	
(variable)	$Ca_4(CaF)(PO_4)_3$	P_2O_5	426	41.6	0.761	1.000	11.25	
		F_2	38	3.7	0.068	0.089	1.00	
			1025	100.0	1.829	2.404	27.05	

Name	Formula	Constituents	Weight	Per cent	Ratio		
Aragonite. *See Calcium carbonate.*							
Arsenolite. *See Arsenous oxide.*							
Arsenous oxide (Arsenolite, cloudetite)	As_2O_3	As_2O_3	197.8	100.0			
Azurite. *See Copper carbonate.*							
Baddeleyite. *See Zirconium oxide.*							
Baking soda. *See Sodium bicarbonate.*							
Barite. *See Barium sulfate.*							
Barium-aluminum-silicate. *See Celsian.*							
Barium carbonate	$BaCO_3$	BaO	153.4	77.7	1.000	3.49	
(Witherite)	$BaO \cdot CO_2$	CO_2	44.0	22.3	0.287	1.00	
			197.4	100.0	1.287	4.49	
Barium chloride	$BaCl_2 \cdot 2H_2O$	$BaCl_2$	208.3	85.3	1.000	5.800	
		H_2O	36.0	14.7	0.173	1.000	
			244.3	100.0	1.173	6.800	
		$BaCl_2 \cdot 2H_2O$	244.3	100.0	1.000	1.595	
		BaO	153.4[a]	100.0	0.6275	1.000	
Barium fluoride	BaF_2	BaF_2	175.4	100.0	1.000		
		BaF_2	175.4	100.0	1.000	1.144	
		BaO	153.4[a]	100.0	0.874	1.000	
Barium hydroxide	$Ba(OH)_2 \cdot 8H_2O$	BaO	153.4	48.6	1.000	0.947	
	$BaO \cdot 9H_2O$	H_2O	162.0	51.4	1.055	1.000	
			315.4	100.0	2.055	1.947	
Barium oxide	BaO	BaO	153.4	100.0			
Barium-silicate	$BaO \cdot SiO_2$	BaO	153.4	71.9	1.000	2.56	
meta-		SiO_2	60.1	28.1	0.391	1.00	
			213.5	100.0	1.391	3.56	
ortho-	$2BaO \cdot SiO_2$	BaO	306.7	83.6	1.000	5.10	
		SiO_2	60.1	16.4	0.196	1.00	
			366.8	100.0	1.196	6.10	
di-	$BaO \cdot 2SiO_2$	BaO	153.4	56.1	1.000	1.28	
		SiO_2	120.2	43.9	0.782	1.00	
			273.6	100.0	1.782	2.28	
Dibarium trisilicate	$2BaO \cdot 3SiO_2$	BaO	306.7	63.0	1.000	1.705	
		SiO_2	180.3	37.0	0.587	1.000	
			487.0	100.0	1.587	2.705	
Barium sulfate	$BaSO_4$	BaO	153.4	65.7	1.000	1.915	
(Barite)	$BaO \cdot SO_3$	SO_3	80.1	34.3	0.522	1.000	
			233.5	100.0	1.522	2.915	
Beryl	$3BeO \cdot Al_2O_3 \cdot 6SiO_2$	BeO	75.1	14.0	1.00	0.736	0.209
		Al_2O_3	101.9	19.0	1.36	1.000	0.274
		SiO_2	360.6	67.0	4.80	3.520	1.000
			537.6	100.0	7.16	5.256	1.483
Beryllium aluminate. *See Chrysoberyl.*							
Beryllium oxide	BeO	BeO	25.0	100.0			
Beryllium silicate. *See Phenacite.*							
Bismuth hydroxide	$Bi(OH)_3$	Bi_2O_3	466.0	89.6	1.000	8.62	
	$Bi_2O_3 \cdot 3H_2O$	H_2O	54.0	10.4	0.116	1.00	
			520.0	100.0	1.116	9.62	
Bismuth oxide	Bi_2O_3	Bi_2O_3	466.0	100.0			
Bismuth subnitrate	$Bi_2O_3 \cdot N_2O_3 \cdot 2H_2O$	Bi_2O_3	466.0	76.4	1.000	4.310	12.95
		N_2O_5	108.0	17.7	0.232	1.000	3.00
		H_2O	36.0	5.9	0.077	0.333	1.00
			610.0	100.0	1.309	5.643	16.95
Bone ash	$4Ca_3(PO_4)_2 \cdot CaCO_3$	CaO	729.3	54.4	1.000	1.284	16.57
	$13CaO \cdot CO_2 \cdot 4P_2O_5$	P_2O_5	568.3	42.3	0.780	1.000	12.91
		CO_2	44.0	3.3	0.061	0.078	1.00
			1341.6	100.0	1.841	2.362	30.48

Name	Formula	Constituents	Weight	Per cent	Ratio		
Borax	$Na_2B_4O_7 \cdot 10H_2O$	Na_2O	62.0	16.3	1.000	0.445	0.345
(Sodium tetraborate)	$Na_2O \cdot 2B_2O_3 \cdot 10H_2O$	B_2O_3	139.2	36.5	2.240	1.000	0.772
		H_2O	180.0	47.2	2.895	1.295	1.000
			381.2	100.0	6.135	2.740	2.117
Borax (melted)	$Na_2O \cdot 2B_2O_3$	Na_2O	62.0	30.8	1.000	0.445	
		B_2O_3	139.2	69.2	2.240	1.000	
			201.2	100.0	3.240	1.445	
Boric acid	$B_2O_3 \cdot 3H_2O$	B_2O_3	69.6	56.3	1.000	1.290	
(Boracic acid)		H_2O	54.0	43.7	0.775	1.000	
			123.6	100.0	1.775	2.290	
Boric oxide	B_2O_3	B_2O_3	69.6	100.0			
Brookite. *See Titanium oxide.*							
Brucite	$Mg(OH)_2$	MgO	40.3	69.1	1.000	2.24	
(Magnesium hydroxide)	$MgO \cdot H_2O$	H_2O	18.0	30.9	0.447	1.00	
			58.3	100.0	1.447	3.24	
Cadmium carbonate	$CdCO_3$	CdO	128.4	74.5	1.000	2.92	
	$CdO \cdot CO_2$	CO_2	44.0	25.5	0.342	1.00	
			172.4	100.0	1.342	3.92	
Cadmium sulfide	CdS	CdS	144.5	100.0	1.000		
(Greenockite)		CdS	144.5	100.0	1.000	1.125	
		CdO	128.4[a]	100.0	0.889	1.000	
Calcite. *See Calcium carbonate.*							
Calcium-aluminate	$CaO \cdot Al_2O_3$	CaO	56.1	35.5	1.000	0.550	
		Al_2O_3	101.9	64.5	1.815	1.000	
			158.0	100.0	2.815	1.550	
Tricalcium	$3CaO \cdot Al_2O_3$	CaO	168.3	62.3	1.000	1.65	
		Al_2O_3	101.9	37.7	0.605	1.00	
			270.2	100.0	1.605	2.65	
3:5	$3CaO \cdot 5Al_2O_3$	CaO	168.3	24.9	1.000	0.330	
		Al_2O_3	509.5	75.1	3.028	1.000	
			677.8	100.0	4.028	1.330	
5:3	$5CaO \cdot 3Al_2O_3$	CaO	280.5	47.9	1.000	0.920	
		Al_2O_3	305.7	52.1	1.085	1.000	
			586.2	100.0	2.085	1.920	
Calcium-aluminum-silicate. *See Anorthite* under *Feldspar.* *See Gehlenite.*							
Calcium-barium-silicate. *See Datolite.*							
Calcium borate	$Ca(BO_2)_2 \cdot 2H_2O$	CaO	56.1	34.7	1.000	0.806	1.560
(Colemanite)	$CaO \cdot B_2O_3 \cdot 2H_2O$	B_2O_3	69.6	43.0	1.240	1.000	1.930
		H_2O	36.0	22.3	0.642	0.518	1.000
			161.7	100.0	2.882	2.324	4.490
Calcium carbonate*	$CaCO_3$	CaO	56.1	56.0	1.000	1.274	
	$CaO \cdot CO_2$	CO_2	44.0	44.0	0.786	1.000	
			100.1	100.0	1.786	2.274	
Calcium chloride	$CaCl_2 \cdot 6H_2O$	$CaCl_2$	111.0	50.6	1.000	1.025	
		H_2O	108.0	49.4	0.974	1.000	
			219.0	100.0	1.974	2.025	
		$CaCl_2 \cdot 6H_2O$	219.0	100.0	1.000	3.90	
		CaO	56.1[a]	100.0	0.257	1.00	
Calcium chloride (anhydrous)	$CaCl_2$	$CaCl_2$	111.0	100.0			
		$CaCl_2$	111.0	100.0	1.000	1.975	
		CaO	56.1[a]	100.0	0.506	1.000	
Calcium fluoride. *See Fluorspar.*							
Calcium-fluorine-phosphate. *See Apatite.*							
Calcium hydroxide	$Ca(OH)_2$	CaO	56.1	75.7	1.000	3.11	
	$CaO \cdot H_2O$	H_2O	18.0	24.3	0.321	1.00	
			74.1	100.0	1.321	4.11	

* Aragonite, calcite, chalk, limestone, marble, whiting.

Name	Formula	Constituents	Weight	Per cent	Ratio			
Calcium-lead-silicate. *See Margarosanite.*								
Calcium-magnesium-carbonate. *See Dolomite.*								
Calcium-magnesium-silicate.								
See Monticellite	$CaO \cdot MgO \cdot SiO_2$							
See Diopside.	$CaO \cdot MgO \cdot 2SiO_2$							
See Akermanite.	$2CaO \cdot MgO \cdot 6SiO_2$							
5:2:1	$5CaO \cdot 2MgO \cdot SiO_2$	CaO	280.5	38.9	1.000	3.50	0.778	
		MgO	80.6	11.1	0.285	1.00	0.222	
		SiO_2	360.6	50.0	1.285	4.50	1.000	
			721.7	100.0	2.570	9.00	2.000	
Calcium oxide (Lime)	CaO	CaO	56.1	100.0				
Calcium phosphate	$Ca_3(PO_4)_2$	CaO	168.3	54.2	1.000	1.185		
(Ortho-)	$3CaO \cdot P_2O_5$	P_2O_5	142.1	45.8	0.845	1.000		
			310.4	100.0	1.845	2.185		
Calcium-phospho-carbonate. *See Bone ash.*								
Calcium silicate.								
See Wollastonite.	$CaO \cdot SiO_2$							
Ortho-	$2CaO \cdot SiO_2$	CaO	112.2	52.4	1.000	1.11		
		SiO_2	101.9	47.6	0.908	1.00		
			214.1	100.0	1.908	2.11		
Tricalcium	$3CaO \cdot SiO_2$	CaO	168.3	62.3	1.000	1.65		
		SiO_2	101.9	37.7	0.605	1.00		
			270.2	100.0	1.605	2.65		
Tricalcium disilicate	$3CaO \cdot 2SiO_2$	CaO	168.3	45.3	1.000	0.828		
		SiO_2	203.8	54.7	1.205	1.000		
			372.1	100.0	2.205	1.828		
Calcium sulfate.								
See Anhydrite.	$CaO \cdot SO_3$							
See Gypsum.	$CaO \cdot SO_3 \cdot 2H_2O$							
Calcium-titanium oxide. *See Perovskite.*								
Calcium tungstate. *See Scheelite.*								
Carbon	C	C	12.0	100.0				
(Graphite, diamond)		C	12.0	100.0	1.000	0.272		
		CO_2	44.0[a]	100 0	3.675	1.000		
Carnallite. *See Potassium carbonate.*								
Carnegieite	$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	Na_2O	62.0	21.8	1.000	0.607	0.515	
(artificial)	$NaAlSiO_4$	Al_2O_3	101.9	35.9	1.645	1.000	0.849	
		SiO_2	120.2	42.3	1.940	1.175	1.000	
			284.1	100.0	4.585	2.782	2.364	
Carnotite	$V_2O_5 \cdot 2UO_3 \cdot K_2O \cdot 3H_2O$	V_2O_5	181.9	20.2	1.000	0.319	1.933	3.36
		UO_3	572.4	63.4	3.135	1.000	6.090	10.56
		K_2O	94.2	10.4	0.515	0.164	1.000	1.73
		H_2O	54.0	6.0	0.297	0.095	0.577	1.00
			902.5	100.0	4.947	1.578	9.600	16.65
Cassiterite. *See Stannic oxide.*								
Caustic. *See Sodium hydroxide.*								
Celestite. *See Strontium sulfate.*								
Celsian	$BaO \cdot Al_2O_3 \cdot 2SiO_2$	BaO	153.4	40.9	1.000	1.506	1.278	
		Al_2O_3	101.9	27.1	0.664	1.000	0.847	
		SiO_2	120.2	32.0	0.783	1.180	1.000	
			375.5	100.0	2.447	3.686	3.125	
Cerium oxide	CeO_2	CeO_2	172.3	100.0	1.000	1.049		
	Ce_2O_3	Ce_2O_3	328.5[a]	100.0	0.954	1.000		
Cerussite. *See Lead carbonate.*								
Chalcanthite. *See Cupric sulfate.*								
Chalk. *See Calcium carbonate.*								
Chrome alum. *See Chromium-potassium-sulfate.*								
Chromite	$FeO \cdot Cr_2O_3$	FeO	71.8	32.1	1.00	0.473		
		Cr_2O_3	152.0	67.9	2.11	1.000		
			223.8	100.0	3.11	1.473		
Chromium oxide	Cr_2O_3	Cr_2O_3	152.0	100.0				

Name	Formula	Constituents	Weight	Per cent	Ratio			
Chromium-potassium-sulfate	$Cr_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	Cr_2O_3	152.0	15.2	1.000	1 614	0.474	0.352
(Chrome alum)	$Cr_2O_3 \cdot K_2O \cdot 4SO_3 \cdot 24H_2O$	K_2O	94.2	9.4	0.619	1.000	0.296	0.218
		SO_3	320.4	32.1	2.105	3.400	1.000	0.742
		H_2O	432.0	43.3	2.840	4.580	1.345	1.000
			998.6	100.0	6.564	10.594	3.115	2.312
Chromium sulfate	$Cr_2(SO_4)_3 \cdot 18H_2O$	Cr_2O_3	152.0	21.2	1.000	0.637	0.469	
	$Cr_2O_3 \cdot 3SO_3 \cdot 18H_2O$	SO_3	240.3	33.5	1.580	1.000	0.741	
		H_2O	324.0	45.2	2.135	1.350	1.000	
			716.3	99.9	4.715	2.987	2.210	
Chrysoberyl	$BeO \cdot Al_2O_3$	BeO	25.0	19.7	1.00	0.239		
		Al_2O_3	101.9	80.3	4.00	1.000		
			126.9	100.0	5.00	1.239		
Cimolite	$2Al_2O_3 \cdot 9SiO_2 \cdot 6H_2O$	Al_2O_3	203.8	23.8	1.000	0.376	1.89	
		SiO_2	540.9	63.4	2.660	1.000	5.01	
		H_2O	108.0	12.8	0.538	0.202	1.00	
			852.7	100.0	4.198	1.578	7.90	
Clay. *See Kaolinite.*								
Clinoenstatite	$MgO \cdot SiO_2$	MgO	40.3	40.2	1.00	0.672		
		SiO_2	60.1	59.8	1.49	1.000		
			100.4	100.0	2.49	1.672		
Cloudetite. *See Arsenous oxide.*								
Cobalt arsenite. *See Smaltite.*								
Cobaltic chloride	$CoCl_3$	$CoCl_3$	165.3	100.0	1.000	1.99		
		Co_2O_3	165.9[a]	100.0	0.502	1.00		
Cobaltic oxide	Co_2O_3	Co_2O_3	165.9	100.0			1.000[a]	1.033
Cobalto-cobaltic oxide	Co_3O_4	Co_2O_3	165.9	68.8	1.000	2.205		
	$Co_2O_3 \cdot CoO$	CoO	75.0	31.2	0.453	1.000		
			240.9	100.0	1.453	3.205	0.969	1.000
Cobaltous acetate	$Co(C_2H_3O_2)_2 \cdot 4H_2O$	CoO	75.0	30.1	1.000	1.56	0.595	
	$CoO \cdot 4C \cdot 7H_2O$	C	48.0	19.3	0.642	1.00	0.381	
		H_2O	126.0	50.6	1.685	2.62	1.000	
			249.0	100.0	3.327	5.18	1.976	
Cobaltous carbonate	$CoCO_3$	CoO	75.0	63.0	1.000	1.700		
(Sphaerocobaltite)	$CoO \cdot CO_2$	CO_2	44.0	37.0	0.587	1.000		
			119.0	100.0	1.587	2.700		
Cobaltous chloride	$CoCl_2 \cdot 6H_2O$	$CoCl_2$	129.9	54.7	1.000	1.205		
		H_2O	108.0	45.3	0.832	1.000		
			237.9	100 0	1.832	2.205		
		$CoCl_2 \cdot 6H_2O$	237.9	100.0	1.000	3.152		
		CoO	75.0[a]	100.0	0.317	1.000		
Cobaltous nitrate	$Co(NO_3)_2 \cdot 6H_2O$	CoO	75.0	25.8	1.00	0.695	0.695	
	$CoO \cdot N_2O_5 \cdot 6H_2O$	N_2O_5	108.0	37.1	1.44	1.000	1.000	
		H_2O	108.0	37.1	1.44	1.000	1.000	
			291.0	100.0	3.88	2.695	2.695	
Cobaltous oxide	CoO	CoO	75.0	100.0				
Cobaltous phosphate	$Co_3(PO_4)_2 \cdot 2H_2O$	CoO	225.0	55.7	1.000	1.580	6.19	
	$3CoO \cdot P_2O_5 \cdot 2H_2O$	P_2O_5	142.1	35.3	0.634	1.000	3.92	
		H_2O	36.0	9.0	0.162	0.255	1.00	
			403.1	100.0	1.796	2.835	11.11	
Cobaltous silicate	Co_2SiO_4	CoO	150.0	71.4	1.000	2.495		
	$2CoO \cdot SiO_2$	SiO_2	60.1	28.6	0.401	1.000		
			210.1	100.0	1.401	3.495		
Cobaltous sulfate	$CoSO_4 \cdot 7H_2O$	CoO	75.0	26.7	1.000	0.937	0.595	
	$CoO \cdot SO_3 \cdot 7H_2O$	SO_3	80.1	28.5	1.065	1.000	0.635	
	(also anhydrous)	H_2O	126.0	44.8	1.680	1.575	1.000	
			281.1	100.0	3.745	3.512	2.230	

Name	Formula	Constituents	Weight	Per cent	Ratio		
Collyrite	$2Al_2O_3 \cdot SiO_2 \cdot 9H_2O$	Al_2O_3	203.8	47.8	1.000	3.39	1.255
		SiO_2	60.1	14.1	0.295	1.00	0.370
		H_2O	162.0	38.1	0.797	2.70	1.000
			425.9	100.0	2.092	7.09	2.625
Colemanite. *See Calcium borate.*							
Copper acetate	$Cu(C_2H_3O_2)_2 \cdot H_2O$	CuO	79.6	39.9	1.000	1.660	1.105
(Cupric)	$CuO \cdot 4C \cdot 4H_2O$	C	48.0	24.0	0.601	1.000	0.665
		H_2O	72.0	36.1	0.905	1.505	1.000
			199.6	100.0	2.506	4.165	2 770
Copper-aluminum-phosphate. *See Turquoise.*							
Copperas. *See Ferrous sulfate.*							
Cordierite	$2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$	MgO	280.5	35.8	1.000	1.375	0.934
(Artif)		Al_2O_3	203.8	25.9	0.724	1.000	0.675
		SiO_2	300.5	38.3	1.070	1.475	1.000
			784.8	100.0	2.794	3.850	2.609
Corrosive sublimate. *See Mercuric chloride.*							
Corundum. *See Alumina.*							
Cotunnite. *See Lead chloride.*							
Crocoite. *See Lead chromate.*							
Cryolite	Na_3AlF_6	NaF	126.0	60.0	1.000	1.500	
	$3NaF \cdot AlF_3$	AlF_3	84.0	40.0	0.667	1.000	
			210.0	100.0	1.667	2.500	
		$3NaF \cdot AlF_3$	210.0	100.0	1.000	2.26	
		Na_2O	62.0[a]	100.0	0.443	1.00	
	$3Na_2O \cdot Al_2O_3 \cdot 6F_2$	Na_2O	183.0	35.7	1.000	1.796	0.803
	(calcined low temp. form)	Al_2O_3	101.9	19.8	0.555	1.000	0.447
		F_2	228.0	44.5	1.245	2.240	1.000
			512.9	100.0	2.800	5.036	2.250
Cupric carbonate (basic)	$CuCO_3 \cdot Cu(OH)_2$	CuO	159.2	71.9	1.000	3.610	8.77
	$2CuO \cdot CO_2 \cdot H_2O$	CO_2	44.0	19.9	0.277	1.000	2.43
	(Malachite)	H_2O	18.0	8.2	0.114	0.412	1.00
			221.2	100.0	1.391	5.022	12.20
(Azurite)	$2CuCO_3 \cdot Cu(OH)_2$	CuO	238.8	69.3	1.000	2.715	13.25
	$3CuO \cdot 2CO_2 \cdot H_2O$	CO_2	88.0	25.5	0.368	1.000	4.90
		H_2O	18.0	5.2	0.075	0.196	1.00
			344.8	100.0	1.443	3.911	19.15
Cupric chloride	$CuCl_2 \cdot 2H_2O$	$CuCl_2$	134.3	78.9	1.000	3.740	
		H_2O	36.0	21.1	0.268	1.000	
			170.3	100.0	1.268	4.740	
		$CuCl_2 \cdot 2H_2O$	170.3	100.0	1.000	2.140	
		CuO	79.6[a]	100.0	0.467	1.000	
Cupric hydroxide	$Cu(OH)_2$	CuO	79.6	81.6	1.000	4.44	
	$CuO \cdot H_2O$	H_2O	18.0	18.4	0.225	1.00	
			97.6	100.0	1.225	5.44	
Cupric nitrate	$Cu(NO_3)_2 \cdot 6H_2O$	CuO	79.6	27.0	1.000	0.74	0.74
	$CuO \cdot N_2O_4 \cdot 6H_2O$	N_2O_5	108.0	36.5	1.356	1.006	1.00
		H_2O	108.0	36.5	1.356	1.006	1.00
			295.6	100.0	3.712	2.712	2.74
Cupric oxide	CuO	CuO	79.6	100.0	1.000	1.112	
		Cu_2O	143.1[a]	100.0	0.899	1.000	
Cupric sulfate	$CuSO_4 \cdot 5H_2O$	CuO	79.6	31.9	1.000	0.994	0.887
(Chalcanthite)	$CuO \cdot SO_3 \cdot 5H_2O$	SO_3	80.1	32.1	1.005	1.000	0.895
		H_2O	90.0	36.0	1.130	1.120	1.000
			249.7	100.0	3.135	3.114	2.782
Cuprite. *See Cuprous oxide.*							
Cuprous hydroxide	CuOH	Cu_2O	71.6	88.9	1.000	8.00	
	$\frac{1}{2}(Cu_2O \cdot H_2O)$	H_2O	9.0	11.1	0.125	1.00	
			80.6	100.0	1.125	9.00	1.000 1.013
		CuO	79.6[a]	100.0			0.988 1.000

Name	Formula	Constituents	Weight	Per cent	Ratio			
Cuprous oxide	Cu_2O	Cu_2O	143.1	100.0	1.000	0.899		
(Cuprite)		CuO	79.6[a]	100.0	1.112	1.000		
Cuprous sulfate	$Cu_2SO_4 \cdot H_2O$	Cu_2O	143.1	59.3	1.000	1.785	7.910	
	$Cu_2O \cdot SO_3 \cdot H_2O$	SO_3	80.1	33.2	0.560	1.000	4.425	
		H_2O	18.0	7.5	0.126	0.226	1.000	
			241.2	100.0	1.686	3.011	13.335	1.000
		CuO	79.6[a]	100.0				0.660
Cyanite. *See Andalusite.*								
Datolite	$2CaO \cdot B_2O_3 \cdot 2SiO_2 \cdot H_2O$	CaO	112.2	35.1	1.000	1.610	0.934	6.27
		B_2O_3	69.6	21.7	0.618	1.000	0.577	3.87
		SiO_2	120.2	37.6	1.070	1.730	1.000	6.72
		H_2O	18.0	5.6	0.159	0.258	0.149	1.00
			320.0	100.0	2.847	4.598	2.660	17.86
Diaspore	$Al_2O_3 \cdot H_2O$	Al_2O_3	101.9	85.0	1.000	5.67		
		H_2O	18.0	15.0	0.176	1.00		
			119.9	100.0	1.176	6.67		
Dickite. *See Kaolinite.*								
Diopside	$CaO \cdot MgO \cdot 2SiO_2$	CaO	56.1	25.9	1.000	1.39	0.467	
		MgO	40.3	18.6	0.719	1.00	0.335	
		SiO_2	120.2	55.5	2.145	2.98	1.000	
			216.6	100.0	3.864	5.37	1.802	
Dolomite	$CaCO_3 \cdot MgCO_3$	CaO	56.1	30.4	1.000	1.390	0.637	
	$CaO \cdot MgO \cdot 2CO_2$	MgO	40.3	21.9	0.720	1.000	0.459	
		CO_2	88.0	47.7	1.567	2.180	1.000	
			184.4	100.0	3.287	4.570	2.096	
Dumortierite	$8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$	Al_2O_3	815.2	64.5	1.000	11.72	2.261	45.30
	$HAl_6BSi_3O_{20}$	B_2O_3	69.6	5.5	0.085	1.00	0.193	3.87
		SiO_2	360.6	28.6	0.443	5.20	1.000	20.00
		H_2O	18.0	1.4	0.022	0.26	0.050	1.00
			1263.4	100.0	1.550	18.18	3.504	70.17
Epsom salts. *See Magnesium sulfate.*								
Feldspar								
Albite	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	Na_2O	62.0	11.8	1.000	0.608	0.172	
(Soda feldspar)		Al_2O_3	101.9	19.4	1.645	1.000	0.282	
		SiO_2	360.6	68.8	5.825	3.545	1.000	
			524.5	100.0	8.470	5.153	1.454	
Oligoclase	$3Na_2O \cdot 2CaO \cdot 5Al_2O_3 \cdot 22SiO_2$	Na_2O	186.0	8.7	1.000	1.67	0.362	0.140
(Soda-lime-feldspar)		CaO	112.2	5.3	0.610	1.00	0.221	0.085
		Al_2O_3	509.5	24.0	2.760	4.54	1.000	0.387
		SiO_2	1322.2	62.0	7.150	11.80	2.580	1.000
			2129.9	100.0	11.520	19.01	4.163	1.612
Anorthite	$CaO \cdot Al_2O_3 \cdot 2SiO_2$	CaO	56.1	20.2	1.00	0.552	0.468	
(Calcic feldspar)		Al_2O_3	101.9	36.6	1.81	1.000	0.848	
		SiO_2	120.2	43.2	2.14	1.180	1.000	
			278.2	100.0	4.95	2.732	2.316	
Orthoclase	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	K_2O	94.2	16.9	1.00	0.923	0.261	
(Microcline)		Al_2O_3	101.9	18.3	1.08	1.000	0.283	
(Potash feldspar)		SiO_2	360.6	64.8	3.83	3.540	1.000	
			556.7	100.0	5.91	5.463	1.544	
Ferric chloride	$FeCl_3 \cdot 6H_2O$	$FeCl_3$	162.2	60.0	1.000	1.50		
		H_2O	108.0	40.0	0.667	1.00		
			270.2	100.0	1.667	2.50		
		$FeCl_3 \cdot 6H_2O$	270.2	100.0	1.0000	6.78		
		Fe_2O_3	79.9[a]	100.0	0.1475	1.00		
Ferric hydroxide	$Fe(OH)_3$	Fe_2O_3	79.9	74.7	1.000	2.95		
	$\frac{1}{2}(Fe_2O_3 \cdot 3H_2O)$	H_2O	27.0	25.3	0.339	1.00		
			106.9	100.0	1.339	3.95		
See Goethite.	$Fe_2O_3 \cdot H_2O$							
See Turgite.	$2Fe_2O_3 \cdot H_2O$							
See Limonite.	$2Fe_2O_3 \cdot 2H_2O$							

Name	Formula	Constituents	Weight	Per cent	Ratio		
Ferric oxide	Fe_2O_3	Fe_2O_3	159.7	100.0			
Ferric phosphate	$FePO_4 \cdot 4H_2O$	Fe_2O_3	79.9	35.8	1.000	1.13	1.110
	$\frac{1}{2}(Fe_2O_3 \cdot P_2O_5 \cdot 8H_2O)$	P_2O_5	71.0	31.9	0.892	1.00	0.987
		H_2O	72.0	32.3	0.902	1.01	1.000
			222.9	100.0	2.794	3.14	3.097
Ferric silicate. *See Iddingsite.*							
Ferric sulfate	$Fe_2(SO_4)_3 \cdot 9H_2O$	Fe_2O_3	159.7	28.4	1 000	0.664	0.987
	$Fe_2O_3 \cdot 3SO_3 \cdot 9H_2O$	SO_3	240.3	42.8	1.505	1.000	1.485
		H_2O	162.0	28.8	1.015	0.673	1.000
			562.0	100.0	3.520	2.337	3.472
Ferric titanium oxide. *See Pseudobrookite.*							
Ferro-ferric oxide. *See Magnetite.*							
Ferrous aluminate. *See Hercynite.*							
Ferrous carbonate	$FeCO_3$	FeO	71.8	62.0	1.000	1.63	
	$FeO \cdot CO_2$	CO_2	44.0	38.0	0.613	1.00	
			115.8	100.0	1.613	2.63	
Ferrous chromate. *See Chromite.*							
Ferrous oxide	FeO	FeO	71.8	100.0	1.000	0.898	
		Fe_2O_3	159.8[a]	100.0	1.111	1.000	
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	FeO	71.8	25.8	1.000	0.896	0.570
(Copperas)	$FeO \cdot SO_3 \cdot 7H_2O$	SO_3	80.1	28.8	1.115	1.000	0.635
		H_2O	126.0	45.4	1.755	1.574	1.000
			277.9	100.0	3.870	3.470	2.205
Ferrous sulfide	FeS_2	FeS_2	120.0	100.0	1.000	1.670	
(Pyrite)		FeO	71.8[a]	100.0	0.597	1.000	
Ferrous-titanium oxide. *See Ilmenite.*							
Fibrolite. *See Andalusite.*							
Flint. *See Silica.*							
Fluorspar	CaF_2	CaF_2	78.1	100.0	1.000		
		CaF_2	78.1	100.0	1.000	1.39	
		CaO	56.1[a]	100.0	0.718	1.00	
Forsterite	$2MgO \cdot SiO_2$	MgO	80.6	57.2	1.000	1.34	
		SiO_2	60.1	42.8	0.747	1.00	
			140.7	100.0	1.747	2.34	
Gahnite	$ZnO \cdot Al_2O_3$	ZnO	81.4	44.3	1.000	0.797	
		Al_2O_3	101.9	55.7	1.255	1.000	
			183.3	100.0	2.255	1.797	
Galena. *See Lead sulfide.*							
Galenite. *See Lead sulfide.*							
Gehlenite	$2CaO \cdot Al_2O_3 \cdot SiO_2$	CaO	112.2	40.9	1.000	1.100	1.865
		Al_2O_3	101.9	37.2	0.910	1.000	1.700
		SiO_2	60.1	21.9	0.536	0.589	1.000
			274.2	100.0	2.446	2.689	4.565
Gibbsite. *See Aluminum hydroxide.*							
Goethite	$Fe_2O_3 \cdot H_2O$	Fe_2O_3	159.7	89.9	1.000	8.90	
		H_2O	18.0	10.1	0.112	1.00	
			177.7	100.0	1.112	9.90	
Goslerite. *See Zinc sulfate.*							
Graphite. *See Carbon.*							
Greenockite. *See Cadmium sulfide.*							
Guillemin. *See Pholerite.*							
Gypsum	$CaSO_4 \cdot 2H_2O$	CaO	56.1	32.6	1.000	0.705	1.56
	$CaO \cdot SO_3 \cdot 2H_2O$	SO_3	80.1	46.5	1.425	1.000	2.22
		H_2O	36.0	20.9	0.640	0.450	1.00
			172.2	100.0	3.065	2.155	4.78
Halloysite	$Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$	Al_2O_3		36.9*	1.000	0.848	1.88
		SiO_2		43.5	1.180	1.000	2.22
		H_2O		19.6	0.531	0.450	1.00
				100.0	2.711	2.298	5.10
Hausmanite	Mn_3O_4	MnO	70.9	31.0	1.000	0.451	
	$MnO \cdot Mn_2O_3$	Mn_2O_3	157.9	69.0	2.227	1.000	
			228.8	100.0	3.227	1.451	

* Average analysis, Norton, p. 54 (11).

Name	Formula	Constituents	Weight	Per cent		Ratio		
Hematite. *See Ferric oxide.*								
Hercynite	$FeO \cdot Al_2O_3$	FeO	71.8	41.3	1.00	0.704		
		Al_2O_3	101.9	58.7	1.42	1.000		
			173.7	100.0	2.42	1.704		
Hydrargillite. *See Aluminum hydroxide.*								
Hydromagnesite. *See Magnesium carbonate.*								
Hydrocerussite. *See Lead carbonate, basic.*								
Iddingsite	$2Fe_2O_3 \cdot 2SiO_2 \cdot 3H_2O$	Fe_2O_3	319.4	64.7	1.000	2.660	5.91	
		SiO_2	120.2	24.3	0.376	1.000	2.23	
		H_2O	54.0	11.0	0.170	0.452	1.00	
			493.6	100.0	1.546	4.112	9.14	
Ilmenite	$FeO \cdot TiO_2$	FeO	71.8	47.3	1.000	0.898		
(*See also Pseudobrookite.*)		TiO_2	80.1	52.7	1.115	1.000		
			151.9	100.0	2.115	1.898		
Indianaite. *See Halloysite.*								
Kalinite. *See Alum, potash.*								
Kaliophilite	$K_2O \cdot Al_2O_3 \cdot 2SiO_2$	K_2O	94.2	29.8	1.000	0.925	0.784	
	$KAlSiO_4$	Al_2O_3	101.9	32.2	1.080	1.000	0.848	
		SiO_2	120.2	38.0	1.275	1.180	1.000	
			316.3	100.0	3.355	3.105	2.632	
Kaolinite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Al_2O_3	101.9	39.5	1.000	0.850	2.830	
(Clay, dickite, nacrite)		SiO_2	120.2	46.5	1.180	1.000	3.340	
		H_2O	36.0	14.0	0.355	0.301	1.000	
			258.1	100.0	2.535	2.151	7.170	
Lead acetate	$Pb(CH_3COO)_2 \cdot 3H_2O$	PbO	223.2	58.8	1.000	4.65	2.065	
	$PbO \cdot 4C \cdot 6H_2O$	C	48.0	12.7	0.216	1.00	0.444	
		H_2O	108.0	28.5	0.485	2.25	1.000	
			379.2	100.0	1.701	7.90	3.509	
Lead antimonate	$3PbO \cdot Sb_2O_5$	PbO	446.4	58.0	1.000	1.38		
Naples yellow		Sb_2O_5	323.4	42.0	0.723	1.00		
			769.8	100.0	1.723	2.38	1.000[a]	1.040
		PbO	446.4	60.5	1.000	1.532		
		Sb_2O_5	291.5	39.5	0.653	1.000		
			737.9	100.0	1.653	2.532	0.962	1.000
Lead borate	$Pb(BO_2)_2 \cdot H_2O$	PbO	223.2	71.8	1.000	3.210	12.35	
	$PbO \cdot B_2O_3 \cdot H_2O$	B_2O_3	69.6	22.4	0.312	1.000	3.86	
		H_2O	18.0	5.8	0.081	0.259	1.00	
			310.8	100.0	1.393	4.469	17.21	
Lead carbonate	$PbCO_3$	PbO	223.2	83.5	1.0000	5.07		
(Cerussite)	$PbO \cdot CO_2$	CO_2	44.0	16.5	0.1975	1.00		
			267.2	100.0	1.1975	6.07		
Lead carbonate	$2PbCO_3 \cdot Pb(OH)_2$	PbO	669.6	86.4	1.000	7.610	37.5	
(Basic white lead)	$3PbO \cdot 2CO_2 \cdot H_2O$	CO_2	88.0	11.3	0.131	1.000	4.9	
(Hydrocerussite)		H_2O	18.0	2.3	0.027	0.203	1.0	
			775.6	100.0	1.158	8.813	43.4	
Lead chloride	$PbCl_2$	$PbCl_2$	278.1	100.0	1.000	1.245		
(Cotunnite)		PbO	223.2[a]	100.0	0.803	1.000		
Lead chromate	$PbCrO_4$	PbO	223.2	69.1	1.000	2.235		
(Crocoite)	$PbO \cdot CrO_3$	CrO_3	100.0	30.9	0.447	1.000		
			323.2	100.0	1.447	3.235	1.000	4.25
		Cr_2O_3	152.0[a]	100.0			0.235	1.00
Lead dioxide	PbO_2	PbO	223.2	93.3	1.000	13.90		
(Brown oxide)	$\frac{1}{3}(2PbO \cdot O_2)$	O_2	16.0	6.7	0.072	1.00		
			239.2	100.0	1.072	14.90		

Name	Formula	Constituents	Weight	Per cent	Ratio			
Lead oxide (Litharge, massicot)	PbO	PbO	223.2	100.0				
Lead oxide (Red lead)	Pb_3O_4	PbO	669.6	97.7	1.000	41.85		
	$^1/_2(6PbO \cdot O_2)$	O_2	16.0	2.3	0.023	1.00		
			685.6	100.0	1.023	42.85		
Lead silicate	$PbO \cdot SiO_2$	PbO	223.2	78.8	1.000	3.72		
meta		SiO_2	60.1	21.2	0.269	1.00		
			283.3	100.0	1.269	4.72		
ortho	$2PbO \cdot SiO_2$	PbO	446.4	88.1	1.000	7.42		
		SiO_2	60.1	11.9	0.135	1.00		
			506.5	100.0	1.135	8.42		
Lead sulfate	$PbSO_4$	PbO	223.2	73.6	1.000	2.79		
(Anglesite)	$PbO \cdot SO_3$	SO_3	80.1	26.4	0.358	1.00		
			303.3	100.0	1.358	3.79		
Lead sulfide	PbS	PbS	239.3	100.0	1.000	1.074		
(Galena, galenite)		PbO	223.2[a]	100.0	0.932	1.000		
Lepidolite	$12SiO_2 \cdot 3Al_2O_3 \cdot 3Li_2O \cdot 2K_2O \cdot 4F_2$	SiO_2	721.2	49.5	1.000	2.359	8.04	3.83
other formulas		Al_2O_3	305.7	21.0	0.424	1.000	3.41	1.62
$(Li,K)_3(F,OH)_2Al_2SiO_3O_5$		Li_2O	89.7	6.2	0.124	0.293	1.00	0.49
$Al_2O_3 \cdot 3SiO_2 \cdot 2(K,Li)F$		K_2O	188.4	12.9	0.261	0.616	2.10	1.00
		F_2	152.0	10.4	0.211	0.497	1.69	0.81
			1457.0	100.0	2.020	4.765	16.24	7.75
Leucite	$K_2O \cdot Al_2O_3 \cdot 4SiO_2$	K_2O	94.2	21.6	1.00	0.924	0.392	
	$KAlSi_2O_6$	Al_2O_3	101.9	23.3	1.08	1.000	0.422	
		SiO_2	240.4	55.1	2.55	2.360	1.000	
			436.5	100.0	4.63	4.284	1.814	
Lime. *See Calcium oxide.*								
Limestone. *See Calcium carbonate.*								
Limonite	$2Fe_2O_3 \cdot 3H_2O$	Fe_2O_3	319.4	85.5	1.000	5.91		
Variable composition. *See Goethite.*		H_2O	54.0	14.5	0.170	1.00		
			373.4	100.0	1.170	6.91		
Litharge. *See Lead oxide.*								
Lithium carbonate	Li_2CO_3	Li_2O	29.9	40.5	1.00	0.68		
		CO_2	44.0	59.5	1.47	1.00		
			73.9	100.0	2.47	1.68		
Lithium oxide	Li_2O	Li_2O	29.9	100.0				
Magnesia. *See Magnesium oxide.*								
Magnesioferrite	$MgO \cdot Fe_2O_3$	MgO	40.3	20.1	1.00	0.252		
		Fe_2O_3	159.7	79.9	3.97	1.000		
			200.0	100.0	4.97	1.252		
Magnesium aluminate. *See Spinel.*								
Magnesium-aluminum-silicate. *See Cordierite.*								
Magnesium carbonate	$MgCO_3$	MgO	40.3	47.8	1.000	0.916		
(Magnesite)	$MgO \cdot CO_2$	CO_2	44.0	52.2	1.090	1.000		
			84.3	100.0	2.090	1.916		
	$MgCO_3 \cdot 3H_2O$	MgO	40.3	29.2	1.000	0.919	0.748	
	$MgO \cdot CO_2 \cdot 3H_2O$	CO_2	44.0	31.8	1.090	1.000	0.815	
		H_2O	54.0	39.0	1.335	1.225	1.000	
			138.3	100.0	3.425	3.144	2.563	
Magnesite, hydro-	$3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$	MgO	161.2	44.1	1.000	1.220	2.23	
	$4MgO \cdot 3CO_2 \cdot 4H_2O$	CO_2	132.0	36.1	0.820	1.000	1.82	
		H_2O	72.0	19.8	0.447	0.545	1.00	
			365.2	100.0	2.267	2.765	5.05	
	$4MgCO_3 \cdot Mg(OH)_2 \cdot 5H_2O$	MgO	201.5	41.5	1.000	1.145	1.865	
	$5MgO \cdot 4CO_2 \cdot 6H_2O$	CO_2	176.0	36.3	0.875	1.000	1.635	
		H_2O	108.0	22.2	0.535	0.612	1.000	
			485.5	100.0	2.410	2.757	4.500	

Name	Formula	Constituents	Weight	Per cent	Ratio			
Magnesium chloride (anhydrous)	$MgCl_2$	$MgCl_2$	95.2	100.0	1.000	2.362		
		MgO	40.3[a]	100.0	0.424	1.000		
(hydrous)	$MgCl_2 \cdot 6H_2O$	$MgCl_2$	95.2	46.9	1.000	0.882		
		H_2O	108.0	53.1	1.135	1.000		
			203.2	100.0	2.135	1.882		
		$MgCl_2 \cdot 6H_2O$	203.2	100.0	1.0000	5.040		
		MgO	40.3[a]	100.0	0.1985	1.000		
Magnesium hydroxide. *See Brucite.*								
Magnesium oxide (magnesia, periclase)	MgO	MgO	40.3	100.0				
Magnesium silicate								
See Clinoenstatite.	$MgO \cdot SiO_2$							
See Forsterite.	$2MgO \cdot SiO_2$							
See Talc (soapstone, steatite).	$3MgO \cdot 4SiO_2 \cdot H_2O$							
Magnesium sulfate (Epsom salts)	$MgSO_4$	MgO	40.3	33.5	1.000	0.504		
		SO_3	80.1	66.5	1.985	1.000		
			120.4	100.0	2.985	1.504		
	$MgSO_4 \cdot 7H_2O$	MgO	40.3	16.4	1.000	0.504	0.321	
		SO_3	80.1	32.5	1.981	1.000	0.636	
		H_2O	126.0	51.1	3.115	1.575	1.000	
			246.4	100.0	6.096	3.079	1.957	
Magnetite	Fe_3O_4	FeO	71.8	31.1	1.000	0.452		
	$FeO \cdot Fe_2O_3$	Fe_2O_3	159.7	68.9	2.224	1.000		
			231.5	100.0	3.224	1.452		
oxidized to	Fe_3O_4	Fe_3O_4	231.5	100.0	1.000	0.967		
	Fe_2O_3	Fe_2O_3	159.7[a]	100.0	1.035	1.000		
Malachite. *See Cupric carbonate.*								
Manganese dioxide (Pyrolusite)	MnO_2	MnO_2	86.9	100.0				
Manganic hydroxide. *See Manganite.*								
Manganic oxide	Mn_2O_3	Mn_2O_3	157.9	100.0	1.000	0.968		
		MnO_2	86.9[a]	100.0	1.100	1.000		
Manganic sulfate	$Mn_2(SO_4)_3$	Mn_2O_3	157.9	39.7	1.00	0.658		
	$Mn_2O_3 \cdot 3SO_3$	SO_3	240.1	60.3	1.52	1.000		
			398.0	100.0	2.52	1.658	1.000	2.290
		MnO_2	86.9[a]	100.0			0.437	1.000
Manganite	$Mn_2O_3 \cdot H_2O$	Mn_2O_3	157.9	89.7	1.000	8.77		
		H_2O	18.0	10.3	0.115	1.00		
			175.9	100.0	1.115	9.77	1.000	1.010
		MnO_2	86.9[a]	100.0			0.989	1.000
Manganosite. *See Manganous oxide.*								
Manganous carbonate (Rhodochrosite)	$MnCO_3$	MnO	70.9	61.7	1.00	1.61		
	$MnO \cdot CO_2$	CO_2	44.0	38.3	0.62	1.00		
			114.9	100.0	1.62	2.61	1.000	1.322
		MnO_2	86.9[a]	100.0			0.756	1.000
Manganous chloride	$MnCl_2 \cdot 4H_2O$	$MnCl_2$	125.8	63.6	1.000	1.745		
		H_2O	72.0	36.4	0.572	1.000		
			197.8	100.0	1.572	2.745		
		$MnCl_2 \cdot 4H_2O$	197.8	100.0	1.000	2.790	2.275	
		MnO	70.9[a]	100.0	0.358	1.000	0.815	
		MnO_2	86.9[a]	100.0	0.439	1.225	1.000	
Manganous hydroxide	$Mn(OH)_2$	MnO	70.9	79.7	1.000	3.93		
	$MnO \cdot H_2O$	H_2O	18.0	20.3	0.254	1.00		
			88.9	100.0	1.254	4.93	1.000	1.023
		MnO_2	86.9[a]	100.0			0.978	1.000
Manganous-manganic oxide. *See Hausmanite.*								
Manganous oxide (Manganosite)	MnO	MnO	70.9	100.0	1.000	0.815		
		MnO_2	86.9[a]	100.0	1.225	1.000		

Name	Formula	Constituents	Weight	Per cent	Ratio			
Manganous sulfate	$MnSO_4 \cdot 4H_2O$	MnO	70.9	31.8	1.000	0.886	0.985	
	$MnO \cdot SO_3 \cdot 4H_2O$	SO_3	80.1	35.9	1.130	1.000	1.111	
		H_2O	72.0	32.3	1.015	0.900	1.000	
			223.0	100.0	3.145	2.786	3.096	1.000
		MnO_2	86.9*	100.0				0.389
	$MnSO_4 \cdot 7H_2O$	MnO	70.9	25.7	1.000	0.890	0.567	
	$MnO \cdot SO_3 \cdot 7H_2O$	SO_3	80.1	28.9	1.129	1.000	0.636	
		H_2O	126.0	45.4	1.766	1.570	1.000	
			277.0	100.0	3.895	3.460	2.203	1.000
		MnO_2	86.9*	100.0				0.313
Manganous-titanium oxide. *See Pyrophanite.*								
Marble. *See Calcium carbonate.*								
Margarosanite	$2CaO \cdot PbO \cdot 3SiO_2$	CaO	112.2	17.5	1.00	0.503	0.367	
		PbO	223.2	34.8	1.99	1.000	0.730	
		SiO_2	305.7	47.7	2.72	1.370	1.000	
			641.1	100.0	5.71	2.873	2.097	
Massicot. *See Lead oxide.*								
Mendozite	$Na_2O \cdot Al_2O_3 \cdot 4SO_3 \cdot 24H_2O$	Na_2O	62.0	6.8	1.00	0.608	0.195	0.144
Also see Natroalunite.	$Na_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$	Al_2O_3	101.9	11.1	1.64	1.000	0.318	0.235
		SO_3	320.2	34.9	5.17	3.145	1.000	0.739
		H_2O	432.0	47.2	6.96	4.240	1.354	1.000
			916.1	100.0	14.77	8.993	2.867	2.118
Mercuric chloride (Corrosive sublimate)	$HgCl_2$	$HgCl_2$	271.5	100.0	1.000	1.250		
		HgO	216.6*	100.0	0.798	1.000		
Mercuric nitrate	$Hg(NO_3)_2 \cdot 2H_2O$	HgO	216.6	60.1	1.000	4.740	3.500	6.01
	$HgO \cdot NO_2 \cdot NO_3 \cdot 2H_2O$	NO_2	46.0	12.7	0.211	1.000	0.738	1.27
	(also anhydrous)	NO_3	62.0	17.2	0.286	1.350	1.000	1.72
		H_2O	36.0	10.0	0.166	0.788	0.572	1.00
			360.6	100.0	1.663	7.878	5.810	10.00
Mercuric oxide	HgO	HgO	216.6	100.0				
Mercuric sulfate	$HgSO_4$	HgO	216.6	73.0	1.00	2.70		
	$HgO \cdot SO_3$	SO_3	80.1	27.0	0.37	1.00		
			296.7	100.0	1.37	3.70		
Mercuric sulfate (Basic)	$2HgO \cdot HgSO_4$	HgO	649.8	89.0	1.000	8.11		
	$3HgO \cdot SO_3$	SO_3	80.1	11.0	0.123	1.00		
			729.9	100.0	1.123	9.11		
Mercuric sulfide	HgS	HgS	232.7	100.0	1.000	1.074		
		HgO	216.6*	100.0	0.932	1.000		
Mercurous oxide	Hg_2O	Hg_2O	417.2	100.0				
Microcline. *See Feldspar, orthoclase.*								
Moissanite. *See Silicon carbide.*								
Molybdenum oxide	MoO_3	MoO_3	144.0	100.0				
Molybdic acid	H_2MoO_4	MoO_3	144.0	88.9	1.000	8.00		
	$MoO_3 \cdot H_2O$	H_2O	18.0	11.1	0.125	1.00		
			162.0	100.0	1.125	9.00		
	$H_2MoO_4 \cdot H_2O$	MoO_3	144.0	80.0	1.000	4.00		
	$MoO_3 \cdot 2H_2O$	H_2O	36.0	20.0	0.250	1.00		
			180.0	100.0	1.250	5.00		
Monticellite	$CaO \cdot MgO \cdot SiO_2$	CaO	56.1	35.9	1.000	1.40	0.934	
		MgO	40.3	25.7	0.716	1.00	0.672	
		SiO_2	60.1	38.4	1.070	1.49	1.000	
			156.5	100.0	2.786	3.89	2.606	
Montmorillonite	$Al_2O_3 \cdot 4SiO_2 \cdot 6H_2O$*	Al_2O_3	101.9	22.6	1.000	0.423	0.942	
		SiO_2	240.4	53.4	2.360	1.000	2.225	
		H_2O	108.0	24.0	1.062	0.449	1.000	
			450.3	100.0	4.422	1.872	4.167	

* Calculated from average analyses in Dana, p. 690 (4).

Name	Formula	Constituents	Weight	Per cent	Ratio			
Mullite	$3Al_2O_3 \cdot 2SiO_2$	Al_2O_3	305.7	71.8	1.000	2.55		
		SiO_2	120.2	28.2	0.393	1.00		
			425.9	100.0	1.393	3.55		
Nacrite. *See Kaolinite.*								
Naples yellow. *See Lead antimonite.*								
Natroalunite	$Na_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$	Na_2O	62.0	7.8	1.000	0.203	0.193	0.574
(Soda alum, *see also Mendozite.*)		Al_2O_3	305.7	38.4	4.920	1.000	0.953	2.830
		SO_3	320.2	40.3	5.170	1.050	1.000	2.965
		H_2O	108.0	13.5	1.730	0.351	0.335	1.000
			795.9	100.0	12.820	2.604	2.481	7.369
Nephelite (artificial). *See Carnegieite.*								
Newtonite	$Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$	Al_2O_3	101.9	34.6	1.000	0.846	1.41	
		SiO_2	120.2	40.9	1.180	1.000	1.67	
		H_2O	72.0	24.5	0.707	0.599	1.00	
			294.1	100.0	2.887	2.445	4.08	
Nickel carbonate	$NiCO_3$	NiO	74.7	62.9	1.000	1.695		
(mono)	$NiO \cdot CO_2$	CO_2	44.0	37.1	0.590	1.000		
			118.7	100.0	1.590	2.695		
Nickelous chloride	$NiCl_2$	$NiCl_2$	129.6	100.0	1.000	1.735		
		NiO	74.7[a]	100.0	0.576	1.000		
	$NiCl_2 \cdot 6H_2O$	$NiCl_2$	129.6	54.5	1.000	1.199		
		H_2O	108.1	45.5	0.834	1.000		
			237.7	100.0	1.834	2.199		
		$NiCl_2 \cdot 6H_2O$	237.7	100.0	1.000	3.18		
		NiO	74.7[a]	100.0	0.314	1.00		
Nickelous-nickelic oxide	Ni_3O_4	NiO	74.7	31.1	1.00	0.452		
	$NiO \cdot Ni_2O_3$	Ni_2O_3	165.4	68.9	2.21	1.000		
			240.1	100.0	3.21	1.452		
Nickelous oxide	NiO	NiO	74.7	100.0				
Nickel sesquioxide	Ni_2O_3	Ni_2O_3	165.4	100.0				
Nickel sulfate	$NiSO_4$	NiO	74.7	48.3	1.00	0.933		
	$NiO \cdot SO_3$	SO_3	80.1	51.7	1.07	1.000		
			154.8	100.0	2.07	1.933		
	$NiSO_4 \cdot 6H_2O$	NiO	74.7	28.4	1.000	0.932	0.691	
	$NiO \cdot SO_3 \cdot 6H_2O$	SO_3	80.1	30.5	1.074	1.000	0.742	
		H_2O	108.0	41.1	1.446	1.348	1.000	
			262.8	100.0	3.520	3.280	2.433	
	$NiSO_4 \cdot 7H_2O$	NiO	74.7	26.6	1.000	0.932	0.594	
	$NiO \cdot SO_3 \cdot 7H_2O$	SO_3	80.1	28.6	1.075	1.000	0.638	
		H_2O	126.0	44.8	1.685	1.575	1.000	
			280.8	100.0	3.760	3.507	2.232	
Octahedrite. *See Titanium oxide.*								
Oligoclase. *See Feldspar.*								
Orthoclase. *See Feldspar.*								
Patronite	V_2S_4	V	102.0	38.9	1.000	0.636	0.389	0.562
		S	160.5	61.1	1.574	1.000	0.611	0.882
			262.5	100.0	2.574	1.636	1.000	1.444
		V_2O_3	181.9[a]	100.0			0.693	1.000
		V	102.0	38.9	0.389	0.682		
		S	160.5	61.1	0.611	1.070		
			262.5	100.0	1.000	1.752		
		V_2O_3	149.9[a]	100.0	0.570	1.000		
Pearl ash. *See Potassium carbonate.*								
Periclase. *See Magensium oxide.*								
Perovskite	$CaO \cdot TiO_2$	CaO	56.1	41.1	1.000	0.698		
		TiO_2	80.1	58.9	1.430	1.000		
			136.2	100.0	2.430	1.698		

Name	Formula	Constituents	Weight	Per cent	Ratio			
Phenacite	$2BeO \cdot SiO_2$	BeO	50.0	45.4	1.000	0.830		
		SiO_2	60.1	54.6	1.205	1.000		
			110.1	100.0	2.205	1.830		
Pholerite	$2Al_2O_3 \cdot 3SiO_2 \cdot nH_2O$*	Al_2O_3		45.0	1.000	1.145	2.87	
(Guillemin)		SiO_2		39.3	0.873	1.000	2.50	
		H_2O		15.7	0.349	0.399	1.00	
				100.0	2.222	2.544	6.37	
	$Al_2O_3 \cdot 3SiO_2 \cdot 4H_2O$†	Al_2O_3	101.9	28.7	1.000	0.564	1.405	
		SiO_2	180.3	50.9	1.770	1.000	2.495	
		H_2O	72.0	20.4	0.707	0.401	1.000	
			354.2	100.0	3.477	1.965	4.900	
Polianite. *See Manganese dioxide.*								
Potassium-aluminum silicate								
See Kaliophilite.	$K_2O \cdot Al_2O_3 \cdot 2SiO_2$							
See Leucite.	$K_2O \cdot Al_2O_3 \cdot 4SiO_2$							
See Orthoclase, under Feldspar.	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$							
Potassium-aluminum-sulfate. *See Alunite.*								
Potassium carbonate								
(Carnallite, pearl ash, sylvite)	K_2CO_3	K_2O	94.2	68.2	1.000	2.14		
	$K_2O \cdot CO_2$	CO_2	44.0	31.8	0.467	1.00		
			138.2	100.0	1.467	3.14		
Potassium carbonate	$K_2O \cdot 2CO_2 \cdot H_2O$	K_2O	94.2	47.0	1.000	1.070	5.22	
(Acid)	$KHCO_3$	CO_2	88.0	44.0	0.935	1.000	4.89	
		H_2O	18.0	9.0	0.191	0.205	1.00	
			200.2	100.0	2.126	2.275	11.11	
Potassium chloride	KCl	KCl	74.6	100.0	1.000			
(Sylvite)		KCl	74.6	100.0	1.000	1.585		
		K_2O	94.2[a]	100.0	0.631	1.000		
Potassium chromate	K_2CrO_4	K_2O	94.2	48.5	1.000	0.942	0.485	1.240
	$K_2O \cdot CrO_3$	CrO_3	100.0	51.5	1.061	1.000	0.515	1.315
			194.2	100.0	2.061	1.942	1.000	2.555
		Cr_2O_3	152.0[a]	100.0			0.391	1.000
Potassium dichromate	$K_2Cr_2O_7$	K_2O	94.2	32.0	1.000	0.471	0.320	0.620
	$K_2O \cdot 2CrO_3$	CrO_3	200.0	68.0	2.125	1.000	0.680	1.335
			294.2	100.0	3.125	1.471	1.000	1.935
		Cr_2O_3	152.0[a]	100.0			0.517	1.000
Potassium hydroxide	KOH	K_2O	47.1	84.0	1.000	5.250		
	$\frac{1}{2}(K_2O \cdot H_2O)$	H_2O	9.0	16.0	0.190	1.000		
			56.1	100.0	1.190	6.250		
Potassium nitrate	KNO_3	K_2O	47.1	46.6	1.000	0.872		
(Niter, saltpeter)	$\frac{1}{2}(K_2O \cdot N_2O_5)$	N_2O_5	54.0	53.4	1.145	1.000		
			101.1	100.0	2.145	1.872		
Potassium oxide	K_2O	K_2O	94.2	100.0				
Potassium permanganate	$KMnO_4$	K_2O	47.1	29.8	1.00	0.425	0.298	0.665
	$\frac{1}{2}(K_2O \cdot Mn_2O_7)$	Mn_2O_7	110.9	70.2	2.35	1.000	0.702	1.565
			158.0	100.0	3.35	1.425	1.000	2.230
		MnO	70.9[a]	100.0			0.448	1.000
		K_2O	47.1	29.8	1.00	0.425	0.298	0.542
		Mn_2O_7	110.9	70.2	2.35	1.000	0.702	1.276
			158.0	100.0	3.35	1.425	1.000	1.818
		MnO_2	86.9[a]	100.0			0.550	1.000
Potassium silicate	$K_2O \cdot SiO_2$	K_2O	94.2	61.0	1.000	1.570		
meta		SiO_2	60.1	39.0	0.638	1.000		
			154.3	100.0	1.638	2.570		

* Norton, p. 60 (11).
† *Colo. Bull.*, p. 431 (5).

Name	Formula	Constituents	Weight	Per cent	Ratio			
meta-, hemihydrate	$K_2O \cdot SiO_2 \cdot {}^1/_2H_2O$	K_2O	94.2	57.7	1.000	1.570	10.50	
		SiO_2	60.1	36.8	0.638	1.000	6.69	
		H_2O	9.0	5.5	0.095	0.149	1.00	
			163.3	100.0	1.733	2.719	18.19	
meta-, hydrous	$K_2O \cdot SiO_2 \cdot H_2O$	K_2O	94.2	54.7	1.000	1.570	5.26	
		SiO_2	60.1	34.9	0.638	1.000	3.36	
		H_2O	18.0	10.4	0.190	0.298	1.00	
			172.3	100.0	1.828	2.868	9.62	
di-	$K_2O \cdot 2SiO_2$	K_2O	94.2	43.9	1.00	0.782		
		SiO_2	120.2	56.1	1.28	1.000		
			214.4	100.0	2.28	1.782		
di-, hydrous	$K_2O \cdot 2SiO_2 \cdot H_2O$	K_2O	94.2	40.6	1.000	0.782	5.27	
		SiO_2	120.2	51.7	1.280	1.000	6.72	
		H_2O	18.0	7.7	0.189	0.149	1.00	
			232.4	100.0	2.469	1.931	12.99	
quadro-, hydrous	$K_2O \cdot 4SiO_2 \cdot H_2O$	K_2O	94.2	26.7	1.000	0.391	5.23	
		SiO_2	240.4	68.2	2.550	1.000	13.40	
		H_2O	18.0	5.1	0.191	0.075	1.00	
			352.6	100.0	3.741	1.466	19.63	
Pseudobrookite	$2Fe_2O_3 \cdot 3TiO_2$	Fe_2O_3	319.4	57.1	1.000	1.330		
		TiO_2	240.3	42.9	0.751	1.000		
			559.7	100.0	1.751	2.330		
Pyrite. *See Ferrous sulfide.*								
Pyrolusite. *See Manganese dioxide.*								
Pyrophanite	$MnO \cdot TiO_2$	MnO	70.9	47.0	1.000	0.887	0.470	0.817
		TiO_2	80.1	53.0	1.127	1.000	0.530	0.923
			151.0	100.0	2.127	1.887	1.000	1.740
		MnO_2	86.9[a]	100.0			0.575	1.000
Pyrophillite	$Al_2O_3 \cdot 4SiO_2 \cdot H_2O$	Al_2O_3	101.9	28.3	1.000	0.424	5.66	
		SiO_2	240.4	66.7	2.360	1.000	13.35	
		H_2O	18.0	5.0	0.177	0.075	1.00	
			360.3	100.0	3.537	1.499	20.01	
Quartz. *See Silica.*								
Rectorite	$Al_2O_3 \cdot 2SiO_2 \cdot H_2O$	Al_2O_3	101.9	42.5	1.000	0.850	5.67	
		SiO_2	120.2	50.0	1.174	1.000	6.67	
		H_2O	18.0	7.5	0.176	0.150	1.00	
			240.1	100.0	2.350	2.000	13.34	
Red lead. *See Lead oxide.*								
Rhodochrosite. *See Manganous carbonate.*								
Roscoelite	$2V_2O_3 \cdot Al_2O_3 \cdot K_2O \cdot 18SiO_2 \cdot 2H_2O$	V_2O_3	299.8	18.6	1.000	2.950	3.180	0.277
	$AlV_2 \cdot KH_2 \cdot Si_9O_{24}$	Al_2O_3	101.9	6.3	0.339	1.000	1.080	0.094
		K_2O	94.2	5.8	0.312	0.920	1.000	0.086
		SiO_2	1081.8	67.1	3.610	10.650	11.480	1.000
		H_2O	36.0	2.2	0.118	0.349	0.379	0.033
			1613.7	100.0	5.379	15.869	17.119	1.490
Rutile. *See Titanium oxide.*								
Salt. *See Sodium chloride.*								
Saltpeter. *See Potassium nitrate.*								
Scheelite	$CaWO_4$	CaO	56.1	19.5	1.000	0.242		
	$CaO \cdot WO_3$	WO_3	232.0	80.5	4.135	1.000		
			288.1	100.0	5.135	1.242		
Selenium oxide	SeO_2	SeO_2	111.2	100.0				
Senarmonite. *See Antimony oxide.*								
Silica*	SiO_2	SiO_2	60.1	100.0				
Silicon carbide	SiC	SiC	40.1	100.0				
(Moissanite)		SiC	40.1	100.0	1.00	0.667		
		SiO_2	60.1[a]	100.0	1.50	1.000		

* Silicon dioxide, cristobalite, flint, quartz, tridymite.

Name	Formula	Constituents	Weight	Per cent	Ratio		
Silicon dioxide. *See Silica.*							
Sillimanite. *See Andalusite.*							
Silver carbonate	Ag_2CO_3	Ag_2O	231.8	84.0	1.000	5.25	
	$Ag_2O \cdot CO_2$	CO_2	44.0	16.0	0.191	1.00	
			275.8	100.0	1.191	6.25	
Silver chloride	AgCl	AgCl	143.3	100.0	1.000	1.238	
		Ag_2O	231.8[a]	100.0	0.808	1.000	
Silver nitrate	$AgNO_3$	Ag_2O	115.9	68.2	1.000	2.145	
	$\frac{1}{2}(Ag_2O \cdot N_2O_5)$	N_2O_5	54.0	31.8	0.467	1.000	
			169.9	100.0	1.467	3.145	
Smaltite	$CoAs_2$	$CoAs_2$	133.9	100.0	1.000	1.785	
		CoO	74.9[a]	100.0	0.560	1.000	
Smithsonite. *See Zinc carbonate.*							
Soapstone. *See Talc.*							
Soda ash. *See Sodium carbonate.*							
Soda niter. *See Sodium nitrate.*							
Sodium-aluminum silicate							
See Carnegieite.	$Na_2O \cdot Al_2O_3 \cdot 2SiO_2$						
See Albite under Feldspar.	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$						
Sodium-aluminum sulfate. *See Natroalunite, mendozite.*							
Sodium antimonate	$2NaSbO_3 \cdot 7H_2O$	Na_2O	62.0	12.2	1.00	0.189	0.488
	$Na_2O \cdot Sb_2O_5 \cdot 7H_2O$	Sb_2O_5	323.5	63.2	5.22	1.000	2.570
		H_2O	126.0	24.6	2.03	0.389	1.000
			511.5	100.0	8.25	1.578	4.058
		Na_2O	62.0	12.0	0.120	0.210	
		Sb_2O_5	323.5	63.4	0.634	1.113	
		H_2O	126.0	24.6	0.246	0.432	
			511.5	100.0	1.000	1.755	
		Sb_2O_5	291.5[a]	100.0	0.569	1.000	
Sodium bicarbonate	$NaHCO_3$	Na_2O	31.0	36.9	1.000	0.704	3.45
(Baking soda)	$\frac{1}{2}(Na_2O \cdot 2CO_2 \cdot H_2O)$	CO_2	44.0	52.4	1.420	1.000	4.90
		H_2O	9.0	10.7	0.290	0.204	1.00
			84.0	100.0	2.710	1.908	9.35
Sodium borate. *See Melted borax.*							
Sodium-calcium-aluminum silicate. *See Oligoclase under Feldspar.*							
Sodium-calcium silicate	$Na_2O \cdot 2CaO \cdot 3SiO_2$	Na_2O	62.0	17.5	1.000	0.554	0.344
1–2–3		CaO	112.2	31.6	1.805	1.000	0.621
		SiO_2	180.3	50.9	2.905	1.610	1.000
			354.5	100.0	5.710	3.164	1.965
1–3–6	$Na_2O \cdot 3CaO \cdot 6SiO_2$	Na_2O	62.0	10.5	1.00	0.369	0.172
		CaO	168.3	28.5	2.71	1.000	0.467
		SiO_2	360.6	61.0	5.82	2.140	1.000
			590.9	100.0	9.53	3.509	1.639
2–1–3	$2Na_2O \cdot CaO \cdot 3SiO_2$	Na_2O	124.0	34.4	1.000	2.21	0.688
		CaO	56.1	15.6	0.453	1.00	0.312
		SiO_2	180.3	50.0	1.455	3.21	1.000
			360.4	100.0	2.908	6.42	2.000
Sodium carbonate	Na_2CO_3	Na_2O	62.0	58.5	1.000	1.41	
(anhydrous)	$Na_2O \cdot CO_2$	CO_2	44.0	41.5	0.709	1.00	
			106.0	100.0	1.709	2.41	
(Washing soda)	$Na_2CO_3 \cdot 10H_2O$	Na_2O	62.0	21.7	1.00	1.41	0.345
	$Na_2O \cdot CO_2 \cdot 10H_2O$	CO_2	44.0	15.4	0.71	1.00	0.245
		H_2O	180.2	62.9	2.90	4.09	1.000
			286.2	100.0	4.61	6.50	1.590
Sodium chloride	NaCl	NaCl	58.4	100.0	1.000	1.889	
(Salt)		Na_2O	62.0[a]	100.0	0.530	1.000	
Sodium chromate	$Na_2CrO_4 \cdot 10H_2O$	Na_2O	62.0	18.1	1.000	0.620	0.344
	$Na_2O \cdot CrO_3 \cdot 10H_2O$	CrO_3	100.0	29.2	1.610	1.000	0.554
		H_2O	180.2	52.7	2.910	1.805	1.000
			342.2	100.0	5.520	3.425	1.898

Name	Formula	Constituents	Weight	Per cent	Ratio		
		Na_2O	62.0	18.1	0.181	0.816	
		CrO_3	100.0	29.2	0.292	1.316	
		H_2O	180.2	52.7	0.527	2.368	
			342.2	100.0	1.000	4.500	
		Cr_2O_3	152.0[a]	100.0	0.222	1.000	
Sodium dichromate	$Na_2Cr_2O_7 \cdot 2H_2O$	Na_2O	62.0	20.8	1.000	0.310	1.72
	$Na_2O \cdot 2CrO_3 \cdot 2H_2O$	CrO_3	200.0	67.1	3.230	1.000	5.55
		H_2O	36.0	12.1	0.582	0.180	1.00
			298.0	100.0	4.812	1.490	8.27
		Na_2O	62.0	20.8	0.208	0.408	
		CrO_3	200.0	67.1	0.671	1.315	
		H_2O	36.0	12.1	0.121	0.237	
			298.0	100.0	1.000	1.960	
		Cr_2O_3	152.0[a]	100.0	0.510	1.000	
Sodium hydroxide	$NaOH$	Na_2O	31.0	77.5	1.00	3.45	
(Caustic)	$\frac{1}{2}(Na_2O \cdot H_2O)$	H_2O	9.0	22.5	0.29	1.00	
			40.0	100.0	1.29	4.45	
Sodium nitrate	$NaNO_3$	Na_2O	31.0	36.5	1.00	0.575	
(Soda niter)	$\frac{1}{2}(Na_2O \cdot N_2O_5)$	N_2O_5	54.0	63.5	1.74	1.000	
			85.0	100.0	2.74	1.575	
Sodium oxide	Na_2O	Na_2O	62.0	100.0			
Sodium silicate	Na_2SiO_3	Na_2O	62.0	50.8	1.000	1.03	
Meta-(anhydrous)	$Na_2O \cdot SiO_2$	SiO_2	60.1	49.2	0.969	1.00	
			122.1	100.0	1.969	2.03	
hydrous	$Na_2SiO_3 \cdot 9H_2O$	Na_2O	62.0	21.8	1.000	1.03	0.381
	$Na_2O \cdot SiO_2 \cdot 9H_2O$	SiO_2	60.1	21.1	0.969	1.00	0.369
		H_2O	162.0	57.1	2.610	2.71	1.000
			284.1	100.0	4.579	4.74	1.750
disilicate	$Na_2O \cdot 2SiO_2$	Na_2O	62.0	34.0	1.00	0.515	
		SiO_2	120.2	66.0	1.94	1.000	
			182.2	100.0	2.94	1.515	
trisilicate	$Na_2O \cdot 3SiO_2$	Na_2O	62.0	25.6	1.00	0.344	
		SiO_2	180.3	74.4	2.91	1.000	
			242.3	100.0	3.91	1.344	
quadro	$Na_2Si_4O_9$	Na_2O	62.0	20.5	1.000	0.258	
	$Na_2O \cdot 4SiO_2$	SiO_2	240.4	79.5	3.888	1.000	
			302.4	100.0	4.888	1.258	
Disodium trisilicate	$2Na_2O \cdot 3SiO_2$	Na_2O	134.0	42.7	1.000	0.744	
		SiO_2	180.3	57.3	1.345	1.000	
			314.3	100.0	2.345	1.744	
Sodium sulfate	Na_2SO_4	Na_2O	62.0	43.7	1.000	0.775	
	$Na_2O \cdot SO_3$	SO_3	80.1	56.3	1.290	1.000	
			142.1	100.0	2.290	1.775	
1–4	$Na_2SO_4 \cdot 7H_2O$	Na_2O	62.0	23.1	1.000	0.775	0.492
	$Na_2O \cdot SO_3 \cdot 7H_2O$	SO_3	80.1	29.9	1.290	1.000	0.636
		H_2O	126.0	47.0	2.030	1.575	1.000
			268.1	100.0	4.320	3.350	2.128
	$Na_2SO_4 \cdot 10H_2O$	Na_2O	62.0	19.2	1.00	0.774	0.343
	$Na_2O \cdot SO_3 \cdot 10H_2O$	SO_3	80.1	24.8	1.29	1.000	0.443
		H_2O	180.0	56.0	2.90	2.247	1.000
			322.1	100.0	5.19	4.021	1.786
Sodium sulfate	$NaHSO_4$	Na_2O	31.0	25.8	1.000	0.387	3.44
(acid)	$\frac{1}{2}(Na_2O \cdot H_2O \cdot 2SO_3)$	SO_3	80.1	66.7	2.585	1.000	8.89
		H_2O	9.0	7.5	0.291	0.112	1.00
			120.1	100.0	3.876	1.499	13.33

Name	Formula	Constituents	Weight	Per cent	Ratio			
Sodium tetraborate. *See Borax.*								
Sodium uranate	Na_2UO_4	Na_2O	62.0	17.8	1.00	0.217		
	$Na_2O \cdot UO_3$	UO_3	286.2	82.2	4.62	1.000		
			348.2	100.0	5.62	1.217		
Sodium uranyl carbonate	$Na_2(UO_2)(CO_3)_2$	Na_2O	62.0	14.2	1.00	0.216	0.703	
	$Na_2CO_3 \cdot (UO_3)(CO_3)$	UO_3	286.2	65.6	4.62	1.000	3.250	
	$Na_2O \cdot UO_3 \cdot 2CO_2$	CO_2	88.0	20.2	1.42	0.308	1.000	
			436.2	100.0	7.04	1.524	4.953	
Sodium vanadate	$NaVO_3$	Na_2O	31.0	25.4	1.000	0.341	0.254	0.414
	$\frac{1}{2}(Na_2O \cdot V_2O_5)$	V_2O_5	91.0	74.6	2.935	1.000	0.746	1.216
			122.0	100.0	3.935	1.341	1.000	1.630
		V_2O_3	149.9[a]	100.0			0.614	1.000
	$Na_3VO_4 \cdot 16H_2O$	Na_2O	93.0	19.7	1.000	1.020	0.323	
	$\frac{1}{2}(3Na_2O \cdot V_2O_5 \cdot 32H_2O)$	V_2O_5	91.0	19.3	0.980	1.000	0.316	
		H_2O	288.0	61.0	3.100	3.160	1.000	
			472.0	100.0	5.080	5.180	1.639	
		Na_2O	93.0	19.7	0.197	1.240		
		V_2O_5	91.0	19.3	0.193	1.215		
		H_2O	288.0	61.0	0.610	3.840		
			472.0	100.0	1.000	6.295		
		V_2O_3	149.9[a]	100.0	0.159	1.000		
Sphaerocobaltite. *See Cobaltous carbonate.*								
Spinel	$MgO \cdot Al_2O_3$	MgO	40.3	28.3	1.00	0.395		
		Al_2O_3	101.9	71.7	2.53	1.000		
			142.2	100.0	3.53	1.395		
Stannic chloride	$SnCl_4$	$SnCl_4$	260.5	100.0	1.000	1.73		
		SnO_2	150.7[a]	100.0	0.579	1.00		
Stannic oxide (Cassiterite)	SnO_2	SnO_2	150.7	100.0				
Stannous chloride	$SnCl_2$	$SnCl_2$	189.6	100.0	1.000	1.408	1.256	
		SnO	134.7[a]	100.0	0.710	1.000		
		SnO_2	150.7[a]	100.0	0.795		1.000	
Stannous oxide	SnO	SnO	134.7	100.0	1.000	0.893		
		SnO_2	150.7[a]	100.0	1.120	1.000		
Stannous oxychloride	$SnO \cdot SnCl_2 \cdot 6H_2O$	SnO	134.7	31.1	1.000	0.709	1.245	
		$SnCl_2$	189.6	43.9	1.410	1.000	1.755	
		H_2O	108.0	25.0	0.804	0.570	1.000	
			432.3	100.0	3.214	2.279	4.000	
		$SnO \cdot SnCl_2 \cdot 6H_2O$	432.3	100.0	1.000	1.605	1.435	
		SnO	134.7[a]	100.0	0.622	1.000		
		SnO_2	150.7[a]	100.0	0.697		1.000	
Stannous sulfate	$SnSO_4$	SnO	134.7	62.7	1.000	1.684	0.627	0.893
	$SnO \cdot SO_3$	SO_3	80.1	37.3	0.594	1.000	0.373	0.532
			214.8	100.0	1.594	2.684	1.000	1.425
		SnO_2	150.7[a]	100.0			0.701	1.000
Steatite. *See Talc.*								
Strontianite. *See Strontium carbonate.*								
Strontium carbonate (Strontianite)	$SrCO_3$	SrO	103.6	70.2	1.000	2.36		
	$SrO \cdot CO_2$	CO_2	44.0	29.8	0.424	1.00		
			147.6	100.0	1.424	3.36		
Strontium oxide	SrO	SrO	103.6	100.0	1.000	0.866		
dioxide	SrO_2	SrO_2	119.6	100.0	1.152	1.000		
Strontium silicate meta	$SrO \cdot SiO_2$	SrO	103.6	63.3	1.000	1.725		
		SiO_2	60.1	36.7	0.579	1.000		
			163.7	100.0	1.579	2.725		

Name	Formula	Constituents	Weight	Per cent	Ratio			
ortho	$2SrO \cdot SiO_2$	SrO	207.2	77.5	1.000	3.45		
		SiO_2	60.1	22.5	0.290	1.00		
			267.3	100.0	1.290	4.45		
Strontium sulfate	$SrSO_4$	SrO	103.6	56.4	1.000	1.295		
(Celestite)	$SrO \cdot SO_3$	SO_3	80.1	43.6	0.773	1.000		
			183.7	100.0	1.773	2.295		
Sylvite. *See Potassium chloride.*								
Talc	$3MgO \cdot 4SiO_2 \cdot H_2O$	MgO	120.9	31.9	1.000	0.503	6.72	
(Steatite, soapstone)		SiO_2	240.4	63.4	1.985	1.000	13.35	
		H_2O	18.0	4.7	0.147	0.074	1.00	
			379.3	100.0	3.132	1.577	21.07	
Thoria	ThO_2	ThO_2	264.2	100.0	1.000			
Thorite	$ThO_2 \cdot SiO_2$	ThO_2	264.2	81.5	1.000	4.40		
		SiO_2	60.1	18.5	0.227	1.00		
			324.3	100.0	1.227	5.40		
Thorium silicate. *See Thorite.*								
Titanium oxide	TiO_2	TiO_2	80.1	100.0	1.000	0.833	1.110	
(Rutile, brookite, octahedrite, anatase)	TiO_2	TiO_2	96.1	100.0	1.200	1.000	1.333	
	Ti_2O_3	Ti_2O_3	144.2	100.0	0.900	0.750	1.000	
Titanium sulfate	$Ti_2(SO_4)_3$	Ti_2O_3	144.2	37.5	1.000	0.600	0.375	0.900
	$Ti_2O_3 \cdot 3SO_3$	SO_3	240.2	62.5	1.666	1.000	0.625	1.500
			384.4	100.0	2.666	1.600	1.000	2.400
		TiO_2	80.1[a]	100.0			0.416	1.000
Tridymite. *See Silica.*								
Tungsten oxide	WO_2	WO_2	216.0	100.0	1.000	0.931		
	WO_3	WO_3	232.0	100.0	1.075	1.000		
Turgite	$2Fe_2O_3 \cdot H_2O$	Fe_2O_3	319.4	94.7	1.000	17.75		
		H_2O	18.0	5.3	0.056	1.00		
			337.4	100.0	1.056	18.75		
Turquoise	$CuO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 9H_2O$	CuO	79.6	9.5	1.00	0.258	0.278	0.487
		Al_2O_3	305.7	36.8	3.87	1.000	1.075	1.885
		P_2O_5	284.2	34.2	3.60	0.930	1.000	1.755
		H_2O	162.0	19.5	2.05	0.530	0.570	1.000
			831.5	100.0	10.52	2.718	2.923	5.127
Uranium oxide	UO_2	UO_2	270.2	100.0	1.000	0.962	0.944	
	U_3O_8	U_3O_8	842.5	100.0	1.040	1.000	0.980	
	UO_3	UO_3	286.2	100.0	1.060	1.020	1.000	
	$UO_4 \cdot 2H_2O$	UO_4	302.2	89.4	1.000	8.39	0.894	1.116
		H_2O	36.0	10.6	0.119	1.00	0.106	0.134
			338.2	100.0	1.119	9.39	1.000	1.250
		UO_2	270.2[a]	100.0			0.800	1.000
Uranium sulfate	$U(SO_4)_2 \cdot 4H_2O$	UO_2	270.2	53.7	1.000	1.685	3.750	
	$UO_2 \cdot 2SO_3 \cdot 4H_2O$	SO_3	160.2	31.9	0.594	1.000	2.225	
		H_2O	72.0	14.4	0.268	0.452	1.000	
			502.4	100.0	1.862	3.137	6.975	
Uranyl nitrate	$UO_2(NO_3)_2 \cdot 6H_2O$	UO_3	286.2	57.0	1.000	2.650	2.650	
	$UO_3 \cdot N_2O_5 \cdot 6H_2O$	N_2O_5	108.0	21.5	0.377	1.000	1.000	
		H_2O	108.0	21.5	0.377	1.000	1.000	
			502.2	100.0	1.754	4.650	4.650	
Uranyl-sodium carbonate. *See Sodium-uranyl carbonate.*								
Valentinite. *See Antimony oxide.*								
Vanadinite	$10PbO \cdot 3V_2O_5 \cdot Cl_2$	PbO	2232.2	78.3	1.000	4.08	31.50	4.950
	$3Pb_3(VO_4)_2 \cdot PbCl_2$	V_2O_5	545.7	19.2	0.245	1.00	7.68	1.215
		Cl_2	70.9	2.5	0.032	0.13	1.00	0.158
			2848.8	100.0	1.277	5.21	40.18	0.623
		V_2O_5	149.9[a]	100.0				1.000

Name	Formula	Constituents	Weight	Per cent	Ratio		
Vanadium-aluminum-potassium silicate. *See Roscoelite.*							
Vanadium-lead chloride. *See Vanadinite.*							
Vanadium sulfide. *See Patronite.*							
Vanadium uranate. *See Carnotite.*							
Washing soda. *See Sodium carbonate.*							
Water glass. *See Sodium silicate.*							
White lead. *See Lead carbonate.*							
Whiting. *See Calcium carbonate.*							
Willemite	$2ZnO \cdot SiO_2$	ZnO	162.8	73.0	1.000	2.70	
		SiO_2	60.1	27.0	0.370	1.00	
			222.9	100.0	1.370	3.70	
Witherite. *See Barium carbonate.*							
Wollastonite	$CaSiO_3$	CaO	56.1	35.5	1.000	0.550	
	$CaO \cdot SiO_2$	SiO_2	101.9	64.5	1.815	1.000	
			158.0	100.0	2.815	1.550	
Zinc aluminate. *See Gahnite.*							
Zinc carbonate	$ZnCO_3$	ZnO	81.4	64.9	1.000	1.848	
(Smithsonite)	$ZnO \cdot CO_2$	CO_2	44.0	35.1	0.541	1.000	
			125.4	100.0	1.541	2.848	
Zincite. *See Zinc oxide.*							
Zinc oxide	ZnO	ZnO	81.4	64.9			
(Zincite)							
Zinc silicate	$ZnO \cdot SiO_2$	ZnO	81.4	57.5	1.000	1.35	
meta		SiO_2	60.1	42.5	0.739	1.00	
			141.5	100.0	1.739	2.35	
See Willemite.	$2ZnO \cdot SiO_2$						
Zinc sulfate	$ZnSO_4$	ZnO	81.4	50.4	1.000	1.015	
anhydrous	$ZnO \cdot SO_3$	SO_3	80.1	49.6	0.986	1.000	
			161.5	100.0	1.986	2.015	
hydrous	$ZnSO_4 \cdot 6H_2O$	ZnO	81.4	30.2	1.000	1.015	0.752
	$ZnO \cdot SO_3 \cdot 6H_2O$	SO_3	80.1	29.7	0.985	1.000	0.740
		H_2O	108.0	40.1	1.330	1.350	1.000
			269.5	100.0	3.315	3.365	2.492
Goslarite	$ZnO \cdot SO_3 \cdot 7H_2O$	ZnO	81.4	28.3	1.000	1.015	0.645
		SO_3	80.1	27.9	0.986	1.000	0.637
		H_2O	126.0	43.8	1.550	1.570	1.000
			287.5	100.0	3.536	3.585	2.282
Zircon	$ZrO_2 \cdot SiO_2$	ZrO_2	123.0	67.2	1.000	2.05	
		SiO_2	60.1	32.8	0.488	1.00	
			183.1	100.0	1.488	3.05	
Zirconia. *See Zirconium oxide.*							
Zirconium oxide	ZrO_2	ZrO_2	123.0	100.0	1.000	0.885	
di-							
per-	ZrO_2	ZrO_2	139.0	100.0	1.130	1.000	
Zirconium silicate. *See Zircon.*							

Comparison of calculations by the molecular and by the table methods.
PROBLEM: To calculate the percentage oxide composition of a glaze from its batch weight.

EXAMPLE 1

MOLECULAR METHOD

	Per cent		Equiv.	K_2O	CaO	PbO	ZnO	Al_2O_3	SiO_2
White lead	52.0	÷ 258.5 =	0.201			0.201			
Feldspar	18.5	÷ 556.8 =	.033	0.033				0.033	0.198
Whiting	5.0	÷ 100.1 =	.050		0.050				
Zinc oxide	4.1	÷ 81.4 =	.050				0.050		
Ball clay	4.3	÷ 258.1 =	.017					0.017	0.034
Flint	16.1	÷ 60.1 =	.268						0.268
	100.0			0.033	0.050	0.201	0.050	0.050	0.500

	Mol.		Mol. wt.		Wt.		Oxide composition, weight (%)
K_2O	= 0.033	×	94.2	=	3.11	÷ 89.93 =	3.4
CaO	= .050	×	56.1	=	2.80	=	3.1
PbO	= .201	×	223.2	=	44.80	=	49.9
ZnO	= .050	×	81.4	=	4.07	=	4.5
Al_2O_3	= .050	×	101.9	=	5.10	=	5.7
SiO_2	= .500	×	60.1	=	30.05	=	33.4
					89.93		100.0

TABLE METHOD

	Per cent	Table factors	K_2O	CaO	PbO	ZnO	Al_2O_3	SiO_2
White lead	52.0	× 0.864			44.90			
Feldspar	18.5	× 0.169	3.13					
		× 0.183					3.39	
		× 0.648						12.00
Whiting	5.0	× 0.560		2.80				
Zinc oxide	4.1	× 1.000				4.10		
Ball clay	4.3	× 0.395					1.70	
		× 0.465						2.00
Flint	16.1	× 1.000						16.10
Unfired weight	100.0		3.13	2.80	44.90	4.10	5.09	30.10

K_2O	3.13	÷ 90.12 =	3.4
CaO	2.80	=	3.1
PbO	44.90	=	49.9
ZnO	4.10	=	4.5
Al_2O_3	5.09	=	5.7
SiO_2	30.10	=	33.4
Fired weight	90.12		100.0

EXAMPLE 2

PROBLEM: To calculate the percentage batch weight of a glaze from its oxide composition.

MOLECULAR METHOD

K_2O	= 3.4	÷ 94.2	=	0.0361
CaO	= 3.1	÷ 56.1	=	0.0552
PbO	= 49.9	÷ 223.2	=	0.2230
ZnO	= 4.5	÷ 81.4	=	0.0552
Al_2O_3	= 5.7	÷ 101.9	=	0.0560
SiO_2	= 33.4	÷ 60.1	=	0.5550
	100.0			

Mol.	K_2O	CaO	PbO	ZnO	Al_2O_3	SiO_2
	0.0361	0.0552	0.2230	0.0552	0.0560	0.5550
White lead 0.223			0.2230			
Whiting 0.0552		0.0552				
Zinc oxide 0.0552				0.0552		
Feldspar 0.0361	0.0361				0.0361	0.2166
Ball clay 0.0199					0.0199	0.3384
Flint 0.2986					0.0199	0.0398
						0.2986
						0.2986

		Batch weight	Per cent
White lead	= 0.223 × 258.5	= 57.7 ÷ 110.8	= 52.0
Feldspar	= 0.0361 × 556.7	= 20.1	= 18.1
Whiting	= 0.0552 × 100.1	= 5.5	= 5.0
ZnO	= 0.0552 × 81.4	= 4.5	= 4.1
Ball clay	= 0.0199 × 258.1	= 5.1	= 4.6
Flint	= 0.2986 × 60.1	= 17.6	= 16.2
		110.5	100.0

TABLE METHOD

	K_2O 3.4	CaO 3.1	PbO 49.9	ZnO 4.5	Al_2O_3 5.7	SiO_2 33.4		
K_2O = 3.4								
CaO = 3.1			49.9				White lead	57.7
PbO = 49.9								
ZnO = 4.5	3.4				3.67	13.03	Feldspar	20.1
Al_2O_3 = 5.7					2.03	20.37		
SiO_2 = 33.4								
100.0		3.1					Whiting	5.5
				4.5			Zinc oxide	4.5
					2.03	2.40	Ball clay	5.1
						17.97	Flint	18.0
								110.9

	Batch weight		Per cent
White lead	= 57.7	÷ 110.9	= 52.0
Feldspar	= 20.1		= 18.1
Whiting	= 5.5		= 5.0
Zinc oxide	= 4.5		= 4.1
Ball clay	= 5.1		= 4.6
Flint	= 18.0		= 16.2
	110.9		100.0

A SIMPLE METHOD FOR OBTAINING PHOTOGRAPHIC RECORDS OF TIME-SETTLE CURVES WITH ELUTRIATION*

By G. Gollnow

ABSTRACT

An "elutriator" is described which does not elutriate but gives the opportunity to obtain a photographic record of the rate of settle of different sized particles. The apparatus and its operation are briefly given.

Analysis by elutriation is frequently employed in ceramics for the determination of particle size. The so-called Wiegner pipe is used for this purpose. It consists of a glass pipe in which a wet preparation of the material to be tested is permitted to settle. With this pipe a narrower measuring pipe communicates which is filled only with the liquid of the preparation, the so-called empty liquid. Due to the change in the specific gravity of the wet preparation during the sedimentation, the level in the measuring pipe changes accordingly. In comparing the lowering of the level with the time, conclusions can be drawn in reference to the desired particle size.

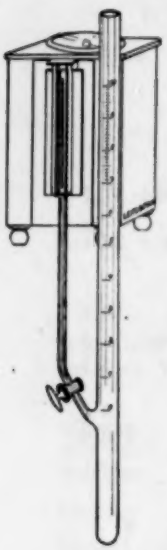

FIG. 1.

In order to follow the lowering of the liquid level conveniently, attempts have been made to photograph the level on paper sensitive to light and arranged on a rotary drum.

Such photographic recording was recently greatly simplified by Stammreich.[1] As seen in Fig. 1, the measuring pipe of the Wiegner pipe is hooked into the photographic recorder, a sedigraph. Immediately before and behind the measuring pipe is a narrow slot; the light passes through this slot and through the liquid onto the paper of the drum. The drum is rotated by a clock. The time can be obtained from the clock dial. One rotation takes place in four hours though the time of rotation may be changed according to the various materials to be tested and the important phases of the settling process.

The apparatus[2] does not possess any special optical equipment and no adjusting is necessary so that it is easily handled. The spacing of the two slots in front of and behind the measuring pipe is such that the clear liquid of the measuring pipe acts as a cylinder lens and the light, falling through the entrance slot, meets the drum in the focal point. An electric bulb of about 40 watts in one meter distance is sufficient.

To obtain a good contrast between the filled and empty part of the measuring pipe, it is advisable to fill the upper part of the liquid with a few drops of a red dye.

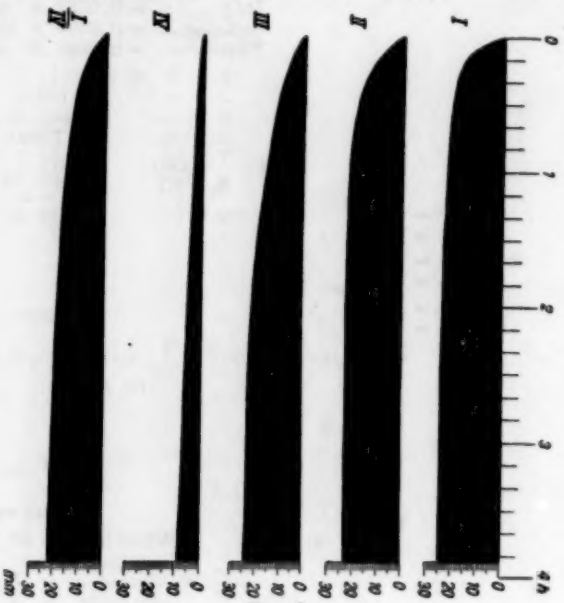

FIG. 2.

For an illustration a few such time-settle curves are shown in Fig. 2. An industrial sand was separated by elutriation into four grades. The curves 1 to 4 correspond to these grades while the last curve was obtained with the original sand.

The calculation can be carried out in the usual manner by placing tangents and by the determination of intersection points with the zero ordinate. In practice, however, where it is essential to obtain a continuous check on the material, a glance over the curve will instantly tell about the grain size. The apparatus is constructed so that the manipulation is exceedingly simple and permits its use in every plant.

Joachim-Friedrichstr. 38
Berlin-Halensee, Germany

* Received May 26, 1933.

[1] Stammreich, *Ber. deut. keram. Ges.*, **14**, 84 (1933).

[2] Manufacturer: Ernst Leitz, Inh.: Franz Bergmann, Berlin.

CERAMIC ABSTRACTS[1]

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Vol. 13 **April, 1934** **No. 4**

Abrasives

Grinder for light work. Norton Co. *Automotive Ind.*, **70** [2], 53 (1934); see also *Ceram. Abs.*, **13** [3], 51 (1934). E.J.V.

Flexibility features swing-frame grinder. Pittsburgh Engineering Works. *Automotive Ind.*, **70** [4], 113 (1934).—The Lectrogrinder, a rapid-type swing-frame grinder, is designed to be hung on any form of crane or trolley support. The grinder may be turned 90° on its side when it is required. E.J.V.

Flexible collecting system. Hunt Spiller Mfg. Corp. *Abrasive Ind.*, **15** [1], 11 (1934).—An apparatus for removing dust from swing-frame grinders is described. Illustrated. A.J.M.

Internal grinder for variety of work. Bryant Chucking Grinder Co. *Automotive Ind.*, **70** [4], 112–13 (1934).—The machine is semiautomatic and fully hydraulic in operation, the diamond holder, cross-feed, and wheel-slide lifter being controlled and operated hydraulically in addition to the traversing of the wheel slide. Illustrated. E.J.V.

Centerless infeed jobs. A. D. Meals. *Abrasive Ind.*, **15** [2], 12–13 (1934).—M. describes several fixtures for a horizontally opposed two-wheel type centerless grinder which permits a variety of work to be ground. Illustrated. A.J.M.

Aluminum housed grinder. Chicago Wheel and Mfg. Co. *Foundry*, **61** [11], 66 (1933).—An aluminum housed portable electric grinder which utilizes over 100 shapes and sizes of abrasive wheels is described. F.G.H.

Inserted tooth reamer grinding. Fred B. Jacobs. *Abrasive Ind.*, **15** [2], 14–15 (1934).—J. describes the manufacture of an inserted tooth reamer and gives drawings. A method of determining the dimensions of angles on the wedges is illustrated. A.J.M.

Grinding supersedes milling in forming tools. II. H. J. Chamberland. *Abrasive Ind.*, **15** [1], 6–7 (1934).—C. describes the finishing of the dovetail and a fixture for forming radii and tells how to change die radius. Several uses of grinding in machine shop operations are mentioned. Illustrated. For Part I see *Ceram. Abs.*, **13** [3], 51 (1934). A.J.M.

Grinding corrosion-resisting castings. Edwin Bremer. *Abrasive Ind.*, **15** [2], 8–9 (1934).—Methods used by the Duriron Co. in finishing high silicon iron castings are described. Illustrated. A.J.M.

Grinding concave grooves. John E. Hyler. *Abrasive Ind.*, **15** [1], 24 (1934).—A method of grinding multiple concave grooves on shafting or other round members is described and a fixture is illustrated. A.J.M.

Universal joints ground rapidly. Gardner Grinding Co. *Abrasive Ind.*, **15** [1], 10 (1934).—A special machine for grinding four surfaces simultaneously is described. Illustrated. A.J.M.

Laboratory testing of polishing abrasives. Fred B. Jacobs. *Metal Cleaning & Finishing*, **6** [1], 32–34 (1934).—The use of simple, slab-type test pieces is discussed. Size of test wheel, speed of operation, and data for comparisons are enumerated and discussed. E.J.V.

Sizing and resizing wire dies. J. J. Kehoe and F. D. Ruhl. *Abrasive Ind.*, **15** [1], 8–9 (1934).—Methods used by the General Electric Co. for finishing and polishing dies are given. A.J.M.

Quantity production of cam rolls. Fred B. Jacobs. *Abrasive Ind.*, **15** [1], 12–13 (1934).—Four methods of finishing cam rolls and two methods of finishing radial face rolls are outlined. Illustrated. A.J.M.

BOOK

Abrasive materials. Paul Hatmaker and A. E. Davis. *Bur. Mines Minerals Yearbook*, 1932–1933. Separate chapter, 20 pp., 5¢. R.A.H.

PATENTS

Apparatus for grinding cutter bars of mowing machines. Alphonse Hirth. U. S. 1,943,529, Jan. 16, 1934.

Sharpener for slicing machines. C. F. M. v. Berkel (U. S. Slicing Machine Co.). U. S. 1,943,642, Jan. 16, 1934.

Manufacture of abrasive articles. H. P. Kirchner. (Carborundum Co.). U. S. 1,944,184, Jan. 23, 1934.

[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

JOSEPH MCKEE (Union Sandpaper Co.). U. S. 1,944,898, Jan. 30, 1934.

Apparatus for testing the hardness of grinding disks. HERBERT LINDNER. U. S. 1,944,353, Jan. 23, 1934.

Grinder. ELY BOCKSHE. U. S. 1,944,489, Jan. 23, 1934.

Cylinder honing tool. F. J. JESCHKE (Micromatic Hone Corp.). U. S. 1,944,660, Jan. 23, 1934.

Honing tool. F. M. KERN (Micromatic Hone Corp.). U. S. 1,944,662, Jan. 23, 1934.

Knife sharpener. G. R. WOOD (International Business Machines Corp.). U. S. 1,944,702, Jan. 23, 1934.

Honing machine. A. M. JOHNSON AND W. M. FAIRBAIRN (Barnes Drill Co.). U. S. 1,945,044, Jan. 30, 1934. A. M. JOHNSON (Barnes Drill Co.). U. S. 1,945,045, Jan. 30, 1934.

Grinding machine. C. H. GERLING (General Electric Co.). U. S. 1,945,396, Jan. 30, 1934. G. H. KENNEDY (Sonoco Products Co.). U. S. 1,945,904, Feb. 6, 1934. H. E. TRACY (O. S. Walker Co., Inc.). U. S. 1,945,986, Feb. 6, 1934. H. F. KOESTLIN, O. H. FOSTER, JR., AND T. J. RICHTER. U. S. 1,946,864, Feb. 13, 1934.

Portable hand abrading machine. A. N. EMMONS (Porter-Cable Machine Co.). U. S. 1,945,425, Jan. 30, 1934.

Stone fluting and molding attachment. L. D. WALLS (Indiana Limestone Co.). U. S. 1,945,471, Jan. 30, 1934.

Combined stone surfacing and sawing machine. A. D. OLDHAM (Indiana Limestone Co.). U. S. 1,945,490, Jan. 30, 1934.

Buffer pad. W. G. RASCH AND J. A. MALCOLM (Burlington Blanket Co.). U. S. 1,945,823, Feb. 6, 1934.

Grinding machine abrasive element. JOSEPH SUNNEN. U. S. 1,946,041, Feb. 6, 1934.

Abrading and polishing device. W. E. MCREYNOLDS (Hugh E. Woodard). U. S. 1,947,054, Feb. 13, 1934.

Knife grinding mechanism. J. A. COMEAU. U. S. 1,946,311, Feb. 6, 1934.

Abrading block. HUGO WURFSCHMIDT (John G. Elbs). U. S. 1,946,562, Feb. 13, 1934.

Machine for dressing emery hobs. E. E. TOUGAS AND M. T. SCHUMB (Boston Gear Works, Inc.). U. S. 1,946,888, Feb. 13, 1934.

Portable electric grinding, polishing, or surfacing machine for stone. F. B. CASSIE. Brit. 403,459, Jan. 3, 1934.

Grinding and abrading wheel. E. OFFENBACHER AKT.-GES. Brit. 403,567, Jan. 3, 1934.

Device for grinding and sharpening razor blades. F. SOUCZEK. Brit. 403,570, Jan. 3, 1934.

Bonding compositions and abrasive articles made therewith. (CARBORUNDUM CO., LTD.). Brit. 403,698, Jan. 10, 1934.

Gear-grinding machine. MAAG-ZAHNRAEDER UND MASCHINEN AKT.-GES. AND D. ERNST. Brit. 403,886, Jan. 10, 1934.

Cylinder grinders. A. E. LAKE. Brit. 403,948, Jan. 17, 1934.

Abrasive elements for abrading tools. R. E. L. WARBURTON. Brit. 404,150 and 404,151, Jan. 17, 1934.

Machines for grinding cylindrical bodies. B. S. A. TOOLS, LTD., AND W. OGILVIE. Brit. 404,403, Jan. 24, 1934.

Art and Archeology

Further development of the underglaze color crayon. KENNETH E. SMITH AND AURELIA ARBO. *Bull. Amer. Ceram. Soc.*, **13** [2], 40–41 (1934).

Overglaze process developed with direct color photography. THOMAS E. CURTIS LABORATORIES. *Ceram. Ind.*, **22** [2], 93 (1934).—An overglaze process of applying direct color photography on ceramics whereby a picture may be reproduced photographically in black and white or in a full range of colors has been developed. The method consists of subjecting ceramic pigments to a special process and then using them to print the picture on cellophane-like sheets with special color plates similar to half-tone printing plates. The sheets are laid on the ware and fired. In firing, the vehicle disappears and the image, consisting of millions of microscopic dots of deeply colored glass, sinks into the glaze. E.J.V.

Color measurement. G. S. FAWCETT. *Chem. & Ind.*, **52** [50], 1005–1007 (1933).—F. describes different methods of measuring color and explains the Lovibond color scale in particular. A.J.M.

Gold engraving under glass. W. B. HONEY. *Connoisseur*, **92** [388], 372–81 (1933).—One of the simplest yet most subtle and refined techniques in pictorial decoration is the engraving through gold leaf laid under glass. A 14th Century account of the process still in use today is given with illustrations and descriptions of examples, mostly from Italy. E.B.H.

Bristol Venetian glass. F. HARMER BROWN. *Connoisseur*, **93** [389], 25–27 (1934).—The characteristics of Venetian glass are its delicate lightness and the applied decoration. The products of Bristol, England, show a trend toward these qualities, since the Venetian workmen hired were too strongly imbued with the traditions to change unless the principles of manufacture were entirely revolutionized. A common example of decoration is the curl in the base of the handle of blue glass cream jugs. B. describes and illustrates examples of elaborate work with the characteristic chains, lattice patterns, trails, grooved stems, hanging droppers, etc. E.B.H.

Faience glazes. JACOB KLUG. *Keram. Rund.*, **41** [43], 571–73; [44], 585–88 (1933).—After discussing conditions required for obtaining glazes of high quality, K. describes the preparation of glazes and experiments with them. It was found that (1) barium oxide can be used to advantage in the glaze composition, and (2) the coloring oxide should be fritted with the glaze to obtain colored glaze. M.V.K.

Suggestions for the production of red glazes. F. W. CORDT. *Ceram. Ind.*, **21** [4], 172–75 (1933); for abstract see *Ceram. Abs.*, **13** [3], 52 (1934). E.J.V.

Red as glaze and decoration color. JACOB KLUG. *Keram. Rund.*, **41** [33], 433–34 (1933).—K. criticizes the paper by W. Cordt (see previous abstract). Details are given on the compositions of (1) chromium red raw glaze for Seger cone 010, (2) chromium red glaze, cone 010, (3) uranium glaze, cone 07a, (4) highly lustrous uranium glaze, cone 03a, (5) dull glaze, cone 03a, (6) gold purple, cone 018, (7) copper-red reduction glaze, cone 05a, (8) leadless Chinese red glaze, cone 4, and (9) white tin glaze. M.V.K.

Terra sigillata. F. LOSSEN. *Sprechsaal*, **66** [49], 835–37; [50], 851–53 (1933).—L. discusses the investigations of Neumann (*Ceram. Abs.*, **11** [8], 461 (1932)) dealing with the terra sigillata glaze and attempts to reproduce it. Illustrated. M.V.K.

Early Virginia glass, Richmond. ANON. *Art*,[1] **27** [1], 41 (1934).—The Richmond Academy of Arts held an exhibit of Colonial and Revolutionary glass revealing the wealth of examples and establishing the fact that one of the first American glass factories was located at Richmond. E.B.H.

Discoveries at Chetro Ketl, New Mexico. WINIFRED REITER AND PAUL REITER. *Illus. London News*, **183**, 892–94 (1933).—The ruins of Chetro Ketl have been revealed after 900 years, disclosing remains unique in American archeology. Illustrated. H.H.S.

Swastika in art. ANON. *Illus. London News*, **183**, 820–21 (1933).—Swastikas occur on cups from Susa of 3000 B.C. and on ancient Greek vases. The geographical distribution of the emblem is shown by a world map. Illustrated. H.H.S.

Chinese ridge tile for roofs. F. DAVIS. *Illus. London News*, **183**, 916 (1933).—Ridge and corner tile were made of glazed figures of rabbits, monkeys, pigeons, and other symbols of the Chinese zodiac. Illustrated. H.H.S.

BOOKS

Chamber Tombs at Mycenae. A. J. B. WACE. xiii + 242 pp., 57 plates. Society of Antiquaries, London, 1933. Price 5 guineas. Reviewed in *Times Lit. Supp.*, **32**, 819 (1933). H.H.S.

Glazed Tile (Azulejos de figura avulsa). FELICIANO GUIMÃRAES. Ediçoes Patria, Gaia, 1933. (In Portuguese.) Reviewed in *Times Lit. Supp.*, **32**, 709 (1933). G. is professor at the University of Coimbra. H.H.S.

PATENTS

Design for teakettle. W. T. CHRISTMAN (Federal Enameling & Stamping Co.). U. S. 91,350, Jan. 16, 1934.

Design for combined cooking kettle and cover. W. T. CHRISTMAN (Federal Enameling & Stamping Co.). U. S. 91,351, Jan. 16, 1934.

Design for combined cooking pan and cover. W. T. CHRISTMAN (Federal Enameling & Stamping Co.). U. S. 91,352, Jan. 16, 1934.

Design for combination coal and gas range. HENRY LANGE (Quincy Stove Mfg. Co.). U. S. 91,359, Jan. 16, 1934.

Design for bottle. C. S. MCPHEE (Everett & Barron Co.). U. S. 91,363, Jan. 16, 1934. F. J. HALE AND W. H. GIBSON. U. S. 91,392, Jan. 23, 1934. J. A. TUMBLER (J. A. Tumbler Laboratories). U. S. 91,474, Feb. 6, 1934. J. P. SGUEGLIA (Anthony Oechs & Co., Inc.). U. S. 91,503, Feb. 13, 1934. J. S. STEIN (Lucien Lelong, Inc.). U. S. 91,504, Feb. 13, 1934.

Design for jar. T. J. PIAZZOLI (Capstan Glass Co.). U. S. 91,366, Jan. 16, 1934.

Design for pitcher. WALTER V. NESSEN (Efcolite Corp.). U. S. 91,376, Jan. 16, 1934.

Design for kettle. P. E. WILLMAN. U. S. 91,380, Jan. 16, 1934.

Design for plate. FERDINAND POPPENHAUSER (Towle Mfg. Co.). U. S. 91,398 and 91,399, Jan. 23, 1934.

Design for bowl. W. W. DODGE, JR. U. S. 91,402, Jan. 23, 1934.

Design for water closet. C. F. MINK. U. S. 91,467, Feb. 6, 1934.

Design for combination cooking utensil. J. C. JOHNSON. U. S. 91,487, Feb. 13, 1934.

[1] The publications, *American Magazine of Art* and *Creative Art*, have combined under the new name, *Art*.

Cements

Status of specifications for hydraulic cements in the United States. P. H. BATES. *Proc. A.S.T.M.*, **33** [Part I], 462–83 (1934).—The possibility of any one type of cement being able to meet adequately the various demands is questioned. The properties of the several types are presented with a discussion of their adaptability to various services. R.A.H.

Cement industry anticipates by-product potash recovery. P. E. LANDOLT. *Chem. Met. Eng.*, **40** [7], 345–49 (1933). One-third to one-half of the potash in the raw material can be considered recoverable. Operating details are given and the data presented from trials and tests show the attainment of a high Cottrell efficiency. A.K.

Microstructure of tricalcium silicate and its importance in cement technique. A. GUTTMANN AND F. GILLE. *Zement*, **22** [16], 204–207; [28], 383–88; [29], 402–405 (1933); *Chim. & ind.*, **30** [6], 1364 (1933).—Tricalcium silicate may absorb small quantities of alumina, iron, manganese, fluorine, and phosphorus pentoxide without changing its principal properties. Researches on the structure of various constituents of cement show that the direction of firing and hydration will be understood only when the structure of separate components is known exactly. Crystallographic measurements show that the crystalline system of tricalcium silicate is trigonal or pseudotrigonal. The relation between the axes $c:a$ is 3.560 ± 0.006. The lengths of the sides of the ordinary hexagonal cell of the silicate are $a = 7$ and $c = 25.0$Å. This cell contains 9 units of $3CaO \cdot SiO_2$. Tricalcium silicate is the chief constituent from the viewpoint of hydraulic action; this action is reinforced by secondary constituents such as aluminates, gypsum, and calcium chloride. M.V.K.

Chemical constitution of hydrated aluminates of calcium. PAUL ERCULISSE AND S. SAPGIR. *Chim. & ind.*

[Special No.], **29** [6], 806–19 (June, 1933).—Methods based on the application of the law of phases were used for the study of aluminates, borates, silicates, and ferrites. The existence of a compound or of a solid solution corresponding to the formula Al_2O_3,4CaO is probable. Dicalcium aluminate does not exist. The results show the existence of a compound Al_2O_3,Ca,Aq. with a formula analogous to that of borax. M.V.K.

PATENT

Process and apparatus for production of Portland and aluminous cements. METALLGES. AKT.-GES. Brit. 404,-863, Jan. 31, 1934.

Enamels

Ground-coat studies. V. Mill additions and consistency. E. P. CZOLGOS. *Better Enameling*, **5** [1], 10–12 (1934).—A ground-coat enamel slip is made up of two-thirds ground-coat frit and one-third water, clay, silica or feldspar, borax, magnesium carbonate, and sometimes bentonite. Water hardness has a noticeable effect on the set of a ground-coat slip. If the water is extremely hard, the enamel comes from the mill with too high an initial set and requires the addition of an excessive amount of water to secure proper dipping consistency. This excess of water causes rapid loss of set, orange peel, and double draining. Clays must be refined so that their plasticity is not destroyed. Silica and feldspar, which increase the firing range of the ground-coat enamel, can be interchanged without affecting the consistency appreciably. Tests on clay suspensions in various solutions of electrolytes showed that (1) clay settles less and reaches stability quicker in water or mill liquor solution that contains ¾% borax, (2) clay settles more in ground-coat mill liquor than it does in pure water, and (3) salts dissolved from ground-coat frits cause more settling of the clay to take place than in pure water. The incorporation of suitable electrolytes in the enamel slip helps to prevent settling. The amount of electrolytes added to the mill charge depends on how much set is desired in the enamel slip for its particular use. It should be understood that the "setting-up" effect of electrolytes does not give a permanent stabilized set condition. Excess amounts of electrolytes for building up "set" are not recommended since they cause more rapid loss of set than would take place ordinarily, but they are a necessity and, used intelligently, are handy tools. Illustrated. For Part IV see *Ceram. Abs.*, **13** [3], 54 (1934). E.J.V.

Bond ground coat. ANON. *Enamelist*, **11** [4], 13–14 (1934).—The mechanics of bond development depend upon chemical and mechanical bond. Chemical bond results from the oxidation of the metal surface and the solution of the resultant iron oxide in the molten enamel. Mechanical bond may be compared to the application of paint on a sandblasted or etched surface *vs.* a smooth or glass-like surface. The bond is increased by the penetration of the molten enamel into the etched or open surface of the metal. Among factors influencing bond development are (1) thorough pickling, (2) a study of the kind of metal surface, (3) proper composition of ground-coat enamel, (4) correct furnace atmosphere during ground-coat firing, (5) correct firing time and temperature, (6) proper grinding of ground-coat enamel, as too fine grinding hinders bond development, and (7) use of a nickel bath or iron sulfide pickle for improving adherence of the ground coat. E.J.V.

Adherence of ground enamel free from adhering oxides. K. MEURES AND A. DIETZEL. *Emailwaren-Ind.*, **10** [44], 349–55; [49], 390–93 (1933); for abstract see *Ceram. Abs.*, **13** [2], 31 (1934). M.V.K.

Danger of lead poisoning through lead enamel. ANON. *Email.*, **1** [3], 5–7 (1933); abstracted in *Emailwaren-Ind.*, **10** [49], 399 (1933).—Dusting is the chief danger. Lead poisoning manifests itself usually with the outbreak of another illness. Wet coating lowers the danger of poisoning. The necessary addition of clay may be replaced by 0.25 to 0.5% Ultra-Sil to avoid opacification. The attempts to produce majolica enamels free from lead have not been successful, although the lead content may be reduced by about 35%. M.V.K.

Reasons for changes in color in cast- and sheet-iron enamels. ANON. *Glashütte*, **63** [34], 571–74 (1933).—A number of factors affect the color tone of the enamel: (1) The use of pure cobalt oxide is not recommended; it absorbs oxygen on calcining and gives it up during fusion of the enamel, producing little swellings. Cobalt oxide should be added to the mill as an aluminate compound. The combining of CoO with Al_2O_3 yields a pigment which does not give up any oxygen and produces a stable color. (2) Manganese oxide is used in the form of manganous peroxide. According to its impurities, it colors brown to red-violet. It should be used as an addition to the mill because it gives up oxygen too easily. The melting should always be done under oxidizing conditions when adding it to the batch. (3) Copper oxide melted with the batch yields a blue-green color. It easily reduces into cuprous oxide which produces a dirty yellow-green. Low melting temperatures and surplus saltpeter are the stabilizers for obtaining a pure color. (4) Chromic oxide is introduced into the enamel as pure oxide. When melted with saltpeter batches it produces yellow-green; its color tone is stable. It produces pure green when melted without saltpeter. (5) Iron oxide is added to the mill or to the batch; in the latter case, there must be a surplus of saltpeter. It yields light red to red-violet according to its degree of oxidation. (6) Nickel oxide is used chiefly for shading other colors. The pigments used chiefly are composed of the following compounds: (*a*) violet tinged with blue is produced by cobalt silicate; (*b*) dark blue, by cobalt aluminate; (*c*) new blue, cobalt aluminate containing chromic oxide; (*d*) light yellow, cadmium sulfide; (*e*) dark yellow, antimonate of lead; (*f*) light red, cadmium sulfoselenite (selenium red); (*g*) green and dark green, pure chromic oxide; (*h*) light green, mixture of cadmium sulfide and new blue; (*i*) violet-blue, mixture of selenium red and new blue. The effects of temperature, treatment during melting, fineness of grinding of the enamel batch,

and composition of the enamel on the color tone are discussed. M.V.K.

Fishscales. VIELHABER. *Emailwaren-Ind.*, **10** [49], 394–95 (1933).—The assumption that the formation of fishscales is due to hydrogen is discussed in detail on the basis of its diffusion in iron. As long as hydrogen migrates in the form of atoms in the iron, it can be easily removed through heating. However, when it strikes inclusions of slag, etc., it transforms into molecular hydrogen and can no longer permeate iron. It gathers and develops high pressure. This molecular hydrogen is probably changed again into atomic hydrogen during calcining of the ware; the included forge scale acts as catalyzer. Since hydrogen diffuses inside slowly it goes out slowly also, partly after fusing, and gathers under the enamel layer diffusing through it and forming fishscales. M.V.K.

Effect of cold weather on enameling. VIELHABER. *Emailwaren-Ind.*, **10** [51], 407–409 (1933).—A detailed discussion of the effect of winter weather on different enameling processes such as pickling, drying, enameling, etc., is given. It is an error to economize on fuel in winter. It is necessary that the pickling batches, the raw ware, the enamel, etc., have a normal temperature to avoid defective enameling. M.V.K.

Enamel painting. VIELHABER. *Emailwaren-Ind.*, **10** [47], 375–77 (1933).—Directions for painting enameled signboards, door signs, etc., are given. Painting with gold, silver, or platinum is discussed. M.V.K.

Majolica enameling. VIELHABER. *Emailwaren-Ind.*, **10** [14], 113–14 (1933).—The advantages and disadvantages of dry and wet methods for applying majolica enamels and the lowering of the lead content of such enamels are discussed. M.V.K.

Tin oxide as white opacifier. H. GERMSCHEID. *Emailwaren- Ind.*, **10** [52], 413–17 (1933).—Tin oxide is obtained by the wet or dry process. German and foreign patents dealing with its production are discussed. The methods are based on (1) the oxidation of tin in tank furnaces by hot air, (2) atomizing tin metal and oxidation of the tin dust, and (3) evaporation of tin and oxidation of the metal vapors. These methods produce a chemically equivalent product, the differences being only of a physical nature. Impurities present in technically produced tin oxide and their effect on enamels are discussed. Tin oxide produced by different methods has practically the same opacifying effect. M.V.K.

Phonolite as enamel raw material. KROSTA AND PFEIFFER. *Glashütte*, **63** [36], 606 (1933).—An account of experiments made to replace feldspar by phonolite in the production of brown enamel for cooking utensils is given. The enamel obtained was of high quality. See also *Ceram. Abs.*, **12** [10–11], 357 (1933). M.V.K.

Barium nitrate as enamel raw material. L. VIELHABER. *Emailwaren-Ind.*, **10** [35], 277 (1933).—Barium batches are excluded in the manufacture of enameled cooking utensils. A replacement of saltpeter by barium nitrate is not advantageous. M.V.K.

Feldspar in enamels. ANON. *Glashütte*, **62** [14], 237 (1932); abstracted in *Emailwaren-Ind.*, **9** [23], 175 (1932).—The importance of feldspar in the manufacture of enamels and the attempt to replace it by other materials are described. It is possible to add to the enamel batch (from the chemical or stoichiometrical viewpoint) materials which feldspar contains, *e.g.*, Al_2O_3 or K_2O, but in practice the results will not be the same because the properties of the enamel will be considerably changed although the chemical analysis will not show any difference. Good results were obtained when replacing feldspar by a kind of glass powder similar in composition to feldspar. The quality of the enamel was better and it was more homogeneous. M.V.K.

Homogeneity of enamel frit and its significance in enamel structure. ANON. *Keram. Rund.*, **41** [35], 460–62 (1933); abstracted in *Emailwaren-Ind.*, **10** [44], 359 (1933).—On the basis of tests, it is shown that a definite granulation of enamel raw materials is best for the fusion process. With too coarse a granulation, the more easily melting ingredients may flow out; with too thin a granulation it is often difficult to discontinue the fusion at the right moment. The gritty state of raw materials is most suitable. The escape of gases formed during fusion proceeds more easily in this state. M.V.K.

Control of raw materials. I. ANON. *Amer. Enameler*, **6** [9], 4–5 (1934).—The proper method of sampling feldspar for making control analyses is described. Treatment of the sample prior to the chemical analysis and methods of determining loss on ignition, silica, iron, calcium oxide, and magnesia are described in detail. E.J.V.

Anhydrous sodium metasilicate for cleaning purposes. COWLES DETERGENT CO. *Metal Cleaning & Finishing*, **6** [1], 36 (1934).—Completely anhydrous sodium metasilicate has the advantage of economy as the ordinary hydrated product contains 42% or more moisture. A solution of the anhydrous product has the same chemical and physical properties and rinses and cleans as efficiently as does the crystalline form. It is also free from dusting. E.J.V.

Practical and technical problems in enameling. E. P. POSTE, G. L. CLARK, A. I. ANDREWS, B. T. SWEELY, AND MAHLON MANSON. *Ceram. Ind.*, **22** [2], 76–78 (1934).—P. reviews recent outstanding developments in the field of enameling from the standpoint of fundamentals, composition, processing, equipment, application, and future possibilities. C. discusses the use of the X-ray and its possibilities in developing information concerning enamels and their physical properties. A., S., and M. discuss chip-proof enamels, enumerating the essentials to reduce chipping. E.J.V.

Light on enamel opacity. ANON. *Ceram. Ind.*, **22** [2], 96–100 (1934).—A review of the data on opacifiers, their use and action, causes of opacity, and other questions on the subject is presented. E.J.V.

Testing enamel coats. ANON. *Tech. Blätter*, No. 12, p. 174 (1933); abstracted in *Emailwaren-Ind.*, **10** [14], 119 (1933).—A brief review of methods employed for testing enameled objects is given. M.V.K.

Notes on enameling. VIII-IX. A. H. *Rev. belge ind. verrières, céram., émail.*, **4** [11], 252; [12], 271 (1933).—A detailed discussion of the pickling of raw ware is given. For Part VII see *Ceram. Abs.*, **13** [2], 31 (1934). M.V.K.

Automatic enameling. ANON. *Emaillerie*, **1** [6], 5–9 (1933); abstracted in *Emailwaren-Ind.*, **10** [49], 399 (1933).—Devices for automatic pickling, enameling with a spraying pistol, drying, and firing are described. M.V.K.

Where the enamel industry belongs. VIELHABER. *Emailwaren-Ind.*, **10** [50], 401–403 (1933).—V. discusses the relationship between the iron, glass, and ceramic industries. M.V.K.

Heat consumption of cooking utensils. H. J. KARMAUS. *Sprechsaal*, **66** [46], 789–90 (1933).—Experiments made to determine the comparative consumption of heat and rate of heating of various types of enameled, porcelain, and metallic cooking utensils are discussed. The results are given in tables. M.V.K.

Firing of enamel. ANON. *Keram. Rund.*, **41** [39], 511–13 (1933).—A general discussion is given of (1) different types of kilns used for enameling, (2) refractories used in them, (3) firing of enamel, and (4) sources of enamel defects. M.V.K.

Control for profit. H. C. GOUDY. *Amer. Enameler*, **6** [2], 3–5 (1933).—A list of the simplest equipment for control tests is given. The tests necessary to maintain control from the pickling room to the finished product are briefly summarized in the order of the progress of the ware through the plant. Illustrated. E.J.V.

Lower costs depend upon perfection of technique. ANON. *Amer. Enameler*, **6** [2], 5 (1933).—To produce the greatest percentage of perfect ware, imperfections must be eliminated from the beginning of the enameling process. Each operation must be complete and perfect if a good cover coat is desired. E.J.V.

Waste in sheet-iron enameling. H. EBRIGHT. *Email.*, **1** [5], 9–14 (1933); abstracted in *Emailwaren-Ind.*, **10** [49], 399 (1933).—The importance of testing sheet iron before enameling, the effect of the quality of clay, other raw materials, fineness of grinding, etc., cleanliness during enameling, and the removal of dust (dust always contains iron) are discussed. Suggestions on the shaping of ware, welding, control, etc., are given. M.V.K.

Porcelain enamel for interior and exterior. CHARLES BACON ROWLEY. *Architecture*, **66** [2], 107–108 (1932).—The use of porcelain enameled iron for both interior and exterior walls of the Ferro Enamel house is described. Illustrated. E.J.V.

Porcelain enameled residence. CHARLES BACON ROWLEY. *Better Enameling*, **5** [1], 20–21 (1934).—A detailed description of the architectural and construction features of the Wheeling Corrugating Co. steel residence is given. Illustrated. E.J.V.

The part of welding in metal houses. BENNETT CHAPPLE. *Iron & Steel Eng.*, **11** [1], 22–24 (1934).—The development of metal house construction is traced from its beginning to the production of the welded Armco-Ferro house exhibited at the Century of Progress, showing how a new welding technique was developed especially for this purpose. Illustrated. See also *Ceram. Abs.*, **12** [6], 217 (1933). E.J.V.

Day-Brite reflectors. ANON. *Better Enameling*, **5** [1], 8–9 (1934).—A résumé of how the Day-Brite Reflector Co., St. Louis, Mo., changed from the electrical contracting business to the manufacture of porcelain-enameled reflectors of all types is given. Illustrated. E.J.V.

Porcelain enamel. HERBERT TÜRK. *Manufacturers Rec.*, **103** [2], 44 (1934).—The Egyptians and other ancients first used porcelain enamel as a preservative for their precious metals and objects of art, while the Chinese were the first commercial enamelers. Through the application of modern science, the cost of production has been decreased and the number of applications has been increased. A résumé of enamel production is given. Among the more recent developments discussed are Glasiron roofing shingles and Glasiron Macotta. Industrial applications of these productions are cited. Illustrated. E.J.V.

Glasiron Macotta. ANON. *Amer. Enameler*, **6** [1], 4 (1933).—Glasiron Macotta is architectural porcelain enamel fused on steel and backed up with Haydite concrete 4 in. thick, forming a practical, substantial, yet decorative building unit. It is jointly manufactured by the Wolverine Porcelain Enameling Co. and the Maul Macotta Corp., Detroit, Mich. Illustrated. E.J.V.

Pemco architectural porcelain enamel defies destruction. ANON. *Amer. Enameler*, **6** [2], 8–9 (1933).—A section of Glasiron Macotta was subjected to a heat treatment of approximately 1000° and quenched with cold water under pressure. After the soot was wiped off it showed no signs of crazing or blistering at any point. Illustrated. E.J.V.

Glasiron Macotta again solves the problem. GEORGE F. DIEHL. *Amer. Enameler*, **6** [9], 12 (1934).—To make an attractive exterior, Glasiron Macotta in two shades of green with ornamental stencil work and trim in blue was used for a store front in Detroit, Mich. Illustrated. E.J.V.

Stran-Steel, a new type of housing. L. S. HAMAKER. *Amer. Enameler*, **6** [2], 6 (1933); see also article by Hoehl, *Ceram. Abs.*, **12** [2], 47 (1933) and *ibid.*, [6], 217 (1933). E.J.V.

Briggs in home equipment field. BRIGGS MFG. CO. *Amer. Enameler*, **5** [9], 7 (1933).—One-piece drawn metal sinks of 14-gage silver etched Brigsteel stock are finished in wet process by a special porcelain enamel which is acid resisting and stainless. Illustrated. E.J.V.

Ten thousand square feet of porcelain enamel on world's largest sign. ANON. *Ceram. Ind.*, **22** [2], 73 (1934).—A display sign for the Chevrolet Motor Co., being erected in Chicago, is 158 ft. long by 148 ft. high and contains 330 tons of steel, most of which is porcelain enameled. Illustrated. E.J.V.

Things to think about in 1934. J. C. WOODSON. *Better Enameling*, **5** [1], 4–6 (1934).—W. discusses electric enameling furnaces and accessories required for proper operation thereof, such as the batch or box type served with charging forks and the continuous conveyer type. A study of the firing room layout with a view toward improving the operating efficiency and decreasing loss of ware is suggested. Hints for electric furnace operation and things to be avoided are listed. Illustrated. E.J.V.

Renovizing the laundry with porcelain enamel. LUCILLE H. MCINTYRE. *Enamelist*, **11** [4], 11–12 (1934).—Among features suggested for modernizing the average home laundry are new stationary tubs, porcelain enameled in colors to harmonize with the electric washer and large enough to rinse a machine-load of clothes at one time, large, easily cleaned tub drains, porcelain-enameled floor drain, clean, nonglaring light from porcelain-enameled reflectors, shelves, gas plates, and sheets to partition the laundry from the rest of the basement. E.J.V.

Frigidaire porcelain plant. ANON. *Enamelist*, **11** [4], 10 (1934).—A description of the Moraine City, Ohio, plant of the Frigidaire Corp., where all the porcelain enamel work is done, is given. Illustrated. E.J.V.

Washer company operating porcelain enameling unit. ANON. *Enamelist*, **11** [4], 16–17 (1934).—The porcelain enameling plant of the Vulcan Mfg. Co., Kansas City, Mo., makers of "Faultless" washing machines, is described. Illustrated. E.J.V.

Two centuries of design in the stove industry. M. JORDAN. *Enamelist*, **11** [4], 17–18 (1934).—Tracing the development in stove design from colonial days to the present, J. describes the porcelain enamel scenic art work being used on modern stoves. Illustrated. E.J.V.

Design of resistance furnaces in Great Britain. A. GLYNNE LOBLEY. *World Power*, **20** [116], 86–89 (1933).—L. discusses developments in the design of electric resistance furnaces of British manufacture for low-temperature work. New methods have been introduced for handling materials. Designs of bright annealing furnaces are described and reference is made to the application of furnaces to vitreous enameling. Illustrated. E.J.V.

Porcelain enameling at the works of the British Thomson-Houston Co., Rugby, England. ANON. *Enamelist*, **11** [4], 19–25 (1934).—A description of the plant and processes for porcelain enameling parts of electric refrigerators and cookers is given. Illustrated. E.J.V.

BOOKS

Principles of Metallurgy. D. M. LIDDELL AND G. E. DOAN. McGraw-Hill Book Co., Inc. 626 pp. Price $5.00. *Can. Chem. Met.*, **18** [1], 35 (1934). E.J.V.

Stamping and Enamel Calendar, 1934 (Stanz- und Emailkalender, 1934). Edited by W. KERSTAN. Ill. Ztg. Blechind. Install., Leipzig C 1. 320 pp. 12.70 Rm. Reviewed in *Emailwaren-Ind.*, **10** [51], 410 (1933).—In the part of the calendar devoted to enamel K. reviews the latest researches dealing with (1) the properties of enamel and its raw materials, (2) theory and practice of opacification, (3) composition, properties, and defects of enamels, (4) metallic underlayers, (5) melting process and melting points, (6) manufacture, (7) special enamels, (8) heat balance of various muffle kilns (coal, electricity, gas), and (9) investigations of raw materials. M.V.K.

PATENTS

Enameling composition. C. J. KINZIE (Titanium Alloy Mfg. Co.). U. S. 1,944,938, Jan. 30, 1934. An enameling or glazing composition for direct application on metal initially comprises in the raw batch the following ingredients substantially in parts by weight: sodium zirconium silicate 10 to 43, aluminum hydrate 0 to 3, potash feldspar 0 to 48, quartz 0 to 24, sodium carbonate 0 to 11, sodium nitrate 3 to 5, calcium carbonate 0 to 8, cryolite 0 to 7, zinc oxide 4 to 14, fluorspar 0 to 11, and borax 23 to 47.

Tiled construction. G. D. HAINES (Porcelain Tile Corp.). U. S. 1,946,690, Feb. 13, 1934.

Glass

Physical processes occurring in the melting and cooling of glass. J. T. LITTLETON. *Jour. Amer. Ceram. Soc.*, **17** [3], 43–49 (1934).

Further studies of the fundamental reactions in the formation of a soda-lime-silica glass. R. F. R. SYKES AND W. E. S. TURNER. Presented at meeting of Society of Glass Technology at Univ. of Leeds, Jan., 1934; *Pottery Gaz.*, **59** [680], 208–10 (1934). E.J.V.

Rejuvenation of raw lime in glassmaking. R. FRINK. *Glass Ind.*, **15** [2], 16–17 (1934).—The use of raw lime by glass manufacturers as a chemical product for glassmaking is cited. It is proved that pure raw lime, free from extraneous matter and carefully mined and classified, will make at less cost a glass uniform in its properties, with a great uniformity of product, operation, distribution, and color and with resistance to solution, bloom, fading, cords, strings, seeds, blisters, etc. E.J.V.

Effect of zirconium oxide on the resistance of heavy baryta-crown glasses. N. G. VOINOT AND A. A. APPEN. *Optic. Mech. Ind.* [U.S.S.R.], **12**, 8 (1932); abstracted in *Sprechsaal*, **66** [48], 825 (1933).—Heavy baryta-crown glasses have a low resistance to acids. It was attempted to ameliorate resistance by changing the glass composition without changing the optical properties. According to Turner, ZrO_2 improves glass stability. In a glass of the composition 31.78% SiO_2, 47.96 BaO, 12.86 B_2O_3, 3.03 Al_2O_3, 2.83 ZnO, and 1.54 As_2O_3 ($n_D = 1.6126 - n_F - n_C = 0.01046$), silica was replaced by increasing additions of ZrO_2. Two series of melts were produced, one in a grog and the other in a platinum crucible. Up to 5% ZrO_2 was added in the form of zirconium mineral. Glass resistance was not improved. M.V.K.

Dilatometric study of ternary silica-soda-glucina glasses. E. RENECKER. *Compt. rend.*, **197**, 840 (1933); abstracted in *Sprechsaal*, **66** [48], 826 (1933).—Silica was dissolved in a concentrated soda-lye solution; the solution was evaporated and the sodium silicate obtained was calcined, mixed with beryllium oxide, and melted in a Garvin and Chaudron vacuum furnace. Colorless glasses were obtained with a vacuum of 1 mm. and gray-colored glasses with 10 mm. air or nitrogen pressure. A strong volatilization of glass ingredients was observed during melting. The cooled glasses were investigated with a Chevenard dilatometer as to their coefficients of expansion and the temperature at which the coefficients change suddenly. Above this point, the glass becomes so soft that it slowly changes shape under the influence of a small load. The expansion depends on the rate of heating. It was found that the replacement of SiO_2 or Na_2O by BeO increases the "transformation temperature." The replacement of Na_2O by BeO lowers the coefficient of expansion, while the substitution of SiO_2 by BeO has no effect. M.V.K.

Properties of selenium-cadmium sulfide glasses. BERNARD LONG. Presented at Internat. Meeting, Milan, 1933; *Keram. Rund.*, **41** [44], 585 (1933); *Glashütte*, **63** [44], 725 (1933); *Sprechsaal*, **66** [52], 887 (1933).—

With certain kinds of glass, colors from lemon-yellow to gold-yellow, red-orange, and red may be obtained by additions of selenium to cadmium sulfide. All these color tones can be obtained in one glass by a suitable thermal treatment. The effect of the height and duration of temperature on the coloring of the glass is discussed. The limits of permeability of lemon-yellow glass lie near 4500Å, of orange-colored glass near 5200Å, and of red glass near 5900Å. The yellow- and orange-colored glasses have a high absorption ability for violet and blue rays but show an increased permeability for yellow and green. M.V.K.

Glass electrode in p_H determination. S. I. Sokolov and A. G. Pasuinskiĭ. *Orladenie Tekn. Kozhevennoe Proizvodstvo*, No. 2, p. 22 (1931); *Jour. Amer. Leather Chemists Assn.*, **28**, 574 (1933).—The reliability of the glass electrode for the range p_H 9 to p_H 14 depends on the composition of the glass and the alkali metals present in the solution. A Li-glass electrode is most reliable in the absence of Li and Na ions. H.H.S.

Thermal endurance of glass. Kozo Tabata and Taro Moriya. *Jour. Soc. Chem. Ind.* [Japan], **36** [11], 575–76*B* (1933); see *Ceram. Abs.*, **13** [3], 56 (1934). M.V.K.

Neodymium glass. C. Wilke. *Chim. & ind.*, **30** [6], 1491 (1933).—A neodymium glass assuring an efficient protection against dazzling from light was produced. It is distinguished by a strong filtration in the ultra-violet region and a strong absorption in the yellow region of the spectrum. A neodymium glass 2 mm. in thickness weakens the intensity of visible light by 50%, but this glass can not be treated in a fusion furnace. It has the property of accentuating contrasts between various colors of the spectrum. M.V.K.

Crystallization of pseudowollastonite during devitrification of glass. Marcel Bellières. Presented at Internat. Meeting, Milan, 1933; *Glashütte*, **63** [43], 834 (1933); *Keram. Rund.*, **41** [44], 585 (1933); *Sprechsaal*, **66** [52], 887 (1933).—The crystals appear usually in the form of small hexagonal plates surrounded by crystals of dendritic shape. The optical properties of pseudowollastonite are exactly defined and may be easily differentiated from other kinds of crystals appearing during devitrification of soda-lime glasses. See also *Ceram. Abs.*, **12** [12], 416 (1933). M.V.K.

Melting behavior of glass of the K_2O–PbO–SiO_2 system. M. A. Besborodov. Presented at Internat. Meeting, Milan, 1933; *Keram. Rund.*, **41** [44], 584 (1933).—The physical and chemical processes occurring during the melting of flint glass were studied. Chemically pure potassium carbonate, minium, and quartz sand were used as raw materials. Studies were made on (1) loss in weight of total mixture, (2) fractional chemical analysis, (3) microscopic testing of melts, and (4) analysis of gaseous materials escaping during melting. The systems K_2CO_3, $K_2CO_3 + Pb_3O_4$, $Pb_3O_4 + SiO_2$, and $K_2CO_3 + SiO_2$ were studied. From the determination of loss in weight and the analysis of escaped gaseous materials, it is concluded that the formation of glass is ended at 800°. The chemical and microscopical analyses show that the process continues above this temperature. M.V.K.

Melting white arsenic enamel for glass. M. F. Shur and V. I. Mozheiko. *Glashütte*, **63** [32], 524–26; [33], 542–44 (1933).—White glass enamel is used for applying white strips on thermometric capillaries, burettes, etc. The enamel must have the same coefficient of expansion as the glass, while the coefficient of elasticity (elasticity modulus), coefficient of Poisson, softening temperature, and tensile strength should correspond to those of the glass. The enamel must be easily fusible. The chemical composition of the enamel should be such that with repeated heating the color will not change which usually occurs because of the reduction of lead or arsenic. White sand, arsenic oxide, lead minium, potassium saltpeter, boric acid, and feldspar or kaolin are used as raw materials. The chemical composition of the enamel shows that SiO_2 and PbO are the chief ingredients (probably present as $PbSiO_3$). PbO with K_2O, Na_2O, and B_2O_3 makes the enamel easily fusible. B_2O_3 and PbO give a special luster, while arsenic oxide makes it opaque. The temperature of fusion is 1250 to 1280°. The flame should never be reducing so as not to precipitate metallic lead and arsenic. Directions for the preparation of the enamel batch and its fusion and cooling are given. M.V.K.

Coloring glass with sulfur and selenium. H. Weckerle. Presented at meeting of German Glass Technical Society, Jan., 1933; *Keram. Rund.*, **41** [15], 188 (1933).—The technically important yellow and brown glasses are obtained with additions of sulfur. Researches on melts with varied iron content showed that iron sulfide is the coloring pigment and not sodium sulfide. In pure selenium glasses, pink color tones were obtained by oxidized melting, and yellow and brown tones with reduced melting. Investigations of the effects of oxidizing and reducing methods of melting on the volatilization of selenium when melting with sodium selenite show great differences. M.V.K.

Amber glass. Anon. *Glass Ind.*, **15** [2], 18–19 (1934).—Lead glass may be given an amber color by the use of selenium under oxidizing conditions. Borax helps to bring out the color and improves the brilliancy of the glass. Selenium amber plains easily. E.J.V.

Physicochemical principles of colored decorations on glass. IV. Jacques Wolf. *Rev. belge ind. verrières, céram., émail.*, **4** [12], 272–73 (1933).—The decorative aspect of mosaic and stained glass and their dependence on a number of physical factors which are enumerated are discussed. For Part III see *Ceram. Abs.*, **12** [12], 417 (1933); this was incorrectly numbered Part IV. Part II was published in *Rev. belge ind. verrières, céram., émail.*, Nos. 4 and 6. M.V.K.

Notes on the manufacture of colorless glasses. No. 23. Anon. *Glass*, **11** [1], 8–11 (1934).—The effect of alumina and boric oxide is discussed. In comparing the effect of oxides on durability the most resistant were, in order, zirconia, alumina, zinc oxide, magnesia, lead oxide, lime, and barium oxide. Values are given on the durability of bottle glasses. For Nos. 20–22 see *Ceram. Abs.*, **13** [3], 57 (1934). A.J.M.

Fading of pigments behind different glasses. Hanns Rein. *Glastech. Ber.*, **11** [6], 193–95 (1933); abstracted in *Keram. Rund.*, **41** [15], 188 (1933).—The assumption that the fading of pigments is due to ultra-violet rays of the sun is contrary to experiments. The color of a pig-

ment is the unabsorbed part of light. The absorbed energy of light is transformed into another form of energy (either heat or chemical energy); visible light plays the most important rôle in the action of the light on pigments. M.V.K.

Using blast-furnace slag in glass manufacture. FRITZ ALTHOF. *Glashütte*, **63** [36], 604–606 (1933).—The granulated blast-furnace slag employed contained no alkalis. The batch containing slag melted easily, and the soda content could be lowered considerably (23%). Because of the presence of sulfur (in the form of CaS) and manganese oxide in the slag, graphite and pyrolusite were not used for coloring the glass. It was found that the sulfur coloring is more certain and uniform. Bottles manufactured from slag batch were stable. Calculations showing the advantages and economy of using slag are given. See also article by Basore, this issue, p. 87. M.V.K.

Glass chipping. C. EARL AVERY. *Glass Ind.*, **15** [2], 17 (1934).—The production of glass decorated by the chipping method is inexpensive. Chipping glue is applied to the glass while in a molten state, allowed to cool, reheated to 200°F, and set on edge in a rack to cool. The glue curls and peels as it dries and contracts and takes splinters of glass along with it, producing an uneven, semitransparent surface. Details of finer decoration by this method are given. E.J.V.

Picture of shadow of a glass body as indication of its quality. ANON. *Keram. Rund.*, **41** [34], 445–46 (1933).—The shadow of a glass body registers any kind of defect appearing in the glass. Illustrated. M.V.K.

Time dependence of water attack in glass. G. KEPPELER AND MAX THOMAS-WETZOW. *Glastech. Ber.*, **11** [6], 205–208 (1933).—The paper deals with (1) chemical and diffusion processes taking place during dissolving of the glass surface and their velocities, and (2) the development and testing of a parabolic function for the dissolving rate (chemical stability) of glass. M.V.K.

Problem of "optical glass" from a technical standpoint. VASCO RONCHI. *Ind. Vetro Ceram.*, **5** [4], 165–70 (1933); abstracted in *Glastech. Ber.*, **11** [6], 218 (1933).—R.'s purpose is to acquaint manufacturers of optical glasses with the problems arising when calculating optical systems and with the selection of appropriate glasses. The properties of optical glasses are treated from the optico-geometrical (index of refraction and Abbé's figure) and the physicochemical (homogeneity and isotropy) points of view. M.V.K.

Relationship between double refraction and elastic properties of rapidly cooled glasses. W. PRIEVE. *Mitt. Hannov. Hochschulgem.* [Berlin], **13**, 68 (1931); abstracted in *Glastech. Ber.*, **11** [5], 185 (1933).—A relationship exists between the double refraction of hardened glasses and the simultaneous change of their elastic properties. Experiments showed that changes in elasticity correspond to changes in hardness. M.V.K.

Studies of chilled plate glass. TSURNO ARAKI, SONOSUKI TAKAHASHI, AND SHUICHI MORI. *Jour. Soc. Chem. Ind.* [Japan], **36** [12], 677*B* (1933).—Examinations of chilled plate glass with a polariscope are discussed. The Young modulus of the glass is unchanged by chilling. Data are given. M.V.K.

Significance and misuse of the designation "hard glass." P. H. PRAUSNITZ AND E. BERGER. *Glastech. Ber.*, **11** [6], 195–99 (1933); abstracted in *Keram. Rund.*, **41** [15], 188 (1933).—The ambiguous term "hard" in connection with glass has been used only for the last fifteen years. New designations are suggested. M.V.K.

Furnaces for the manufacture of hardened safety glass. H. G. BODENBENDER. *Rev. belge ind. verrières, céram., émail.*, **4** [12], 275–76 (1933).—B. discusses the chilling of glass, conditions required to obtain safety glasses of good quality, and furnaces employed for hardening. M.V.K.

Present state and development of safety glass. FRITZ OHL. *Keram. Rund.*, **41** [42], 588–90 (1933).—O. discusses (1) materials used for the intermediate layer, (2) organic artificial glass, and (3) utilization of hard glass in the manufacture of safety glass. M.V.K.

Heat transfer in an industrial glass heat exchanger. H. C. BATES. *Chem. Met. Eng.*, **40** [10], 512–13 (1933).—B. gives results of recent experiments conducted in the laboratories of the Corning Glass Works. The heat-transfer measurements were carried out by measuring the rise in temperature of the water passed through the tube at various steam pressures and water rates. The heat transfer increases with both increasing mean-temperature difference and increasing water-flow rate. The results are summarized in an accompanying tabulation. A.K.

Effect of gases on the properties of glass. VII–VIII. K. NAKANISHI. *Jour. Soc. Chem. Ind.* [Japan], **36** [12], 672–73*B* (1933).—The velocity of silver plating upon the glass surface is influenced by the heat treatment of the glass, *e.g.*, in the case of heating in dry air under normal pressure and below its softening temperature the higher the temperature and the longer its duration, the more difficult it is to silver plate; when heating above the softening temperature, the reverse result is obtained. For Part VI see *Ceram. Abs.*, **13** [3], 59 (1934). M.V.K.

Scientific principles of fuel economy in the glass industry. VI. DAVID BROWNLIE. *Glass*, **11** [1], 14–18 (1934).—B. describes combined low-temperature carbonization and total gasification at the Hazel-Atlas Glass Works. Several patented producers are described and illustrated. For Part V see *Ceram. Abs.*, **13** [3], 69 (1934). A.J.M.

Developments in recuperative glasspot furnaces. T. TEISEN. Presented at meeting of the Society of Glass Technology at Stourbridge, Jan., 1934; *Pottery Gaz.*, **59** [680], 211 (1934). E.J.V.

Flow of glass in tanks. II. H. HAUSNER. *Ceram. Ind.*, **22** [2], 81–86 (1934); for Part I see *Ceram. Abs.*, **13** [3], 59 (1934). E.J.V.

Fourcault installations for a small production. F. STANG. *Glashütte*, **63** [32], 523–24; [33], 540–42 (1933).—Data are given on the cost of building a two-machine Fourcault installation with a production of 8000 kg. glass in 24 hr. M.V.K.

Gas for annealing glassware in a continuous leer. E. J. MENEREY. *Gas Engr.*, **50** [9], 407–408 (1933).—A 60-ft. leer of the continuous type heated by surface combustion inspiration-type burners was found to deposit a light white film known as "bloom" on the glassware. Experiments showed this deposit to be due to the organic sulfur

compounds in the gas, and varying proportions of hydrogen were added to the gas to decrease the proportion of sulfur compounds. Under the operating conditions, with the glass in the high-temperature zone for 45 min. when running on a 80-min. cycle, the maximum allowable sulfur content in the gas to prevent "bloom" is 3 grains. Details of the laboratory experiments are given. E.J.V.

Tank furnace systems for mechanical sheet-glass operation. A. M. *Glashütte*, **63** [26], 445–46 (1933).—Present tank furnace systems have (1) a zone of glass formation, (2) a refining zone, and (3) a drawing zone. A complete shut-off of the melting and refining parts from the drawing zone increases and improves the output and quality of the glass. This method permits more intensive heating of the melting and refining parts of the furnace. The shape and construction of the tank are significant in relation to the quality of the glass. M.V.K.

Cooling refractory brick in the tank. O. Bartsch, H. Blank, H. Jebsen-Marwedel, W. Koenig, and A. Schild. *Fachausschussber. Deut. Glastech. Ges.*, No. 23 (1932); abstracted in *Chim. & ind.*, **30** [6], 1368 (1933).—Cooling refractory brick in a tank furnace is erroneous as it accelerates the transversal flows and activates the erosive action of the glass on brick. After a certain length of service, however, the brick should be cooled. In this case, cooling should be concentrated on joints; glass should be solidified in the fissures and joints. Cooling of the brick is effectual only when the glass thickens greatly in contact with the brick whose thickness is inferior to 50 mm. The best protection of joints is obtained by blowing cold air directly on the glass. M.V.K

Essentials of glass technology based on American practice. VI. S. R. Scholes. *Ceram. Ind.*, **22** [2], 102–104 (1934).—Glasshouse fuels, including under solid fuels wood and bituminous coal, under liquid the various oils, and under gaseous natural gas, producer gas, coal gas, and coke-oven gas, are briefly discussed. Illustrated. For Part V see *Ceram. Abs.*, **13** [3], 56 (1934). E.J.V.

Scientific bases of glass research. W. Weyl. *Sklarske Rozhledy*, **8** [3], 36–40 (1931); abstracted in *Glastech. Ber.*, **11** [5], 182–83 (1933).—W. discusses methods for determining equilibrium in silicates. The transition of silicate melts from the glassy into the crystallized state in its dependence on undercooling is explained by means of a diagram. M.V.K.

Progress of the glass industry in 1932. Oscar Knapp. *Glashütte*, **63** [41], 675–76 (1933).—K. briefly reviews the following topics: (1) crystal chemistry of silicates, (2) arrangement of atoms in glass, (3) state of undercooled liquids and glasses, (4) nature of the glassy state, (5) constitution of glass according to the solvation theory, (6) volumes of technical glasses, (7) 3-component system, potassium, sodium silicates, and silica, (8) melting diagram of the system PbO–SiO_2, (9) reactions between calcium carbonate and SiO_2, (10) rate of disintegration of calcium carbonate, (11) volatilization of soda-silica glasses, (12) synthetic calcium silicates. References are given. M.V.K.

Quality control: the planning of statistical tests. B. P. Dudding. Presented at meeting of Society of Glass Technology at Univ. of Leeds, Jan., 1934; *Pottery Gaz.*, **59** [680], 210 (1934). E.J.V.

Air conditioning saves six years in polishing world's largest mirror. M. M. Lawler. *Heating, Piping, & Air Conditioning*, **5** [11], 547–51 (1933).—It is estimated that air conditioning will reduce the time required to grind and polish the new 200-in. telescope mirror, under construction at the Calif. Inst. of Tech., from 9 to 3 years. The building and the air-conditioning system installed therein are described. A general description of the way in which this huge Pyrex brand mirror is to be ground, polished, and tested is included. Illustrated. J.L.G.

Lighting fixtures, Rockefeller Center. Anon. *Architecture*, **67** [3], 153 (1933).—Unusual light sources, in which there are intricate provisions for safety from falling and from glass breakage, were developed for this purpose. Heat-resisting glass is used in some of the fixtures. Illustrated. See also article by Skerrett, *Ceram. Abs.*, **13** [2], 37 (1934). E.J.V.

Illuminated glass mural. Maurice Heaton. *Architecture*, **66** [6], 351 (1932).—A description of the mural of Amelia Earhart's flight across the Atlantic developed in glass and erected in the new Roxy Theater, Rockefeller Center, New York, is given. Illustrated. E.J.V.

Entrance doors of carved glass. Hambidge Warner. *Architecture*, **66** [1], 37–38 (1932).—A history of costume design is utilized in the carved glass door panels for a modern salon. Illustrated. E.J.V.

Lead and glass in silhouette. Eugene Clute. *Architecture*, **65** [1], 13–20 (1932).—C. discusses examples of the type of leaded glass in which the lead forms the design in silhouette while the glass fills the voids. This type affords a means of enrichment to which the usual leaded glass is not so well adapted. Illustrated. E.J.V.

Glass mosaic. Eugene Clute. *Architecture*, **64** [3], 141–46 (1931).—The reception room of the Irving Trust Co., New York, in which the wall and ceiling surfaces are broken by angular changes of plane, is covered, above a marble dado extending 3 ft. from the floor, by a glass mosaic which grades from a dark red up to an orange on the ceiling. The gradation of colors appears like an effect of lighting. Complete details of the pattern and its development and manner of installation are given. Illustrated. E.J.V.

Modern decorative light sources. Eugene Clute. *Architecture*, **64** [2], 71–76 (1931).—Developments in lighting sources in which glass tubes, troughs, sheets, molded glass, and various metals are combined are described. Illustrated. E.J.V.

New and unusual uses of glass. A. E. Marshall. *Glass Ind.*, **15** [2], 18 (1934).—Among new developments in glass are a tin can with glass top and bottom, infra-red absorbing glasses, high lead (30%) glasses for X-ray handling, glass spools for artificial silk manufacture, glass insulators, etc. E.J.V.

Gigantic steel conduits for Boulder Dam. R. G. Skerrett. *Glass Ind.*, **15** [2], 13–15 (1934).—X-ray tubes 4 ft. long with a bulb 8 in. in diameter, made of Pyrex brand glass $^1/_4$ in. thick, are being used in making structural examinations by means of radiographic films of the electrically welded steel conduits 30 ft. in diameter, of $2^3/_4$ in. steel, being made by the Babcock & Wilcox Co. for the Boulder Dam. The X-ray tubes are of such

power that a radiograph can be made of steel up to 4½ in. in thickness. Illustrated. E.J.V.

Modern uses of glass. GEORGE LOVELL. Presented at meeting of Society of Glass Technology, London, Jan., 1934; *Pottery Gaz.*, **59** [680], 210 (1934). E.J.V.

Old English glass. No. 48. FRANCIS BUCKLEY. *Glass*, **11** [1], 12–13 (1934).—Several curious pieces of glass are described. Illustrated. For No. 47 see *Ceram. Abs.*, **13** [3], 59 (1934). A.J.M.

BULLETIN

Producing glass from furnace slag. C. A. BASORE. *Bull. Alabama Polytech. Inst.*, No. 3; *Chem. Met. Eng.*, **40** [6], 309 (1933).—The interesting possibilities of blast-furnace slag as a raw material for glass are discussed. Several types of the slag glass have been developed on an experimental scale. Possible uses are given. See also *Ceram. Abs.*, **12** [6], 219 (1933) and article by Althof, this issue, p. 85. A.K.

PATENTS

Glass construction. H. W. WELD. U. S. 1,943,995, Jan. 16, 1934.

Stop-light lens. J. B. DICKSON (General Motors Research Corp.). U. S. 1,944,154, Jan. 23, 1934.

Means for producing laminated glass. A. C. SCHOEPFER. U. S. 1,944,277, Jan. 23, 1934.

Apparatus for tempering glass sheets. CHARLES ZIEGLER (American Securit Co.). U. S. 1,944,625, Jan. 23, 1934.

Method and apparatus for forming glassware. K. E. PEILER AND A. J. SMITH (Hartford-Empire Co.). U. S. 1,944,844, Jan. 23, 1934. K. E. PEILER (Hartford-Empire Co.). U. S. 1,944,866, Jan. 23, 1934.

Method and apparatus for making glass. H. A. WADMAN (Hartford-Empire Co.). U. S. 1,944,855, Jan. 23, 1934. This method of making glass comprises supplying glassmaking materials to a batch of molten glass at a rate substantially equal to the rate of withdrawal of finished glass from the batch.

Glass product and method of manufacturing sponge-like glass. BERNARD LONG (Soc. anon. des manufactures des glaces et produits chimiques de St.-Gobain, Chauny et Cirey). U. S. 1,945,052, Jan. 30, 1934.

Lens for signal lamps. A. H. HANDLAN. U. S. 1,945,190, Jan. 30, 1934.

Lens system. PAUL RUDOLPH. U. S. 1,945,570, Feb. 6, 1934.

Glass apparatus. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 1,945,601, Feb. 6, 1934.

Method and apparatus for making wire glass. C. B. KINGSLEY (Mississippi Glass Co.). U. S. 1,945,695, Feb. 6, 1934.

Method and apparatus for feeding molten glass. S. G. STUCKEY (Obear-Nester Glass Co.). U. S. 1,945,871, Feb. 6, 1934.

Manufacture of hollow glassware. G. E. ROWE (Hartford-Empire Co.). U. S. 1,945,982 and 1,945,983, Feb. 6, 1934.

Manufacture of glass bottles and apparatus therefor. A. E. SMITH (Hartford-Empire Co.). U. S. 1,945,985, Feb. 6, 1934.

Plate glass polishing block. R. A. MILLER (Pittsburgh Plate Glass Co.). U. S. 1,946,355, Feb. 6, 1934.

Glass cutting apparatus. WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 1,946,356, Feb. 6, 1934.

Fitting form for glass plates. JOHN WYND (Duplate Corp.). U. S. 1,946,377, Feb. 6, 1934.

Plate glass rolling apparatus. J. H. FOX (Pittsburgh Plate Glass Co.). U. S. 1,946,397, Feb. 6, 1934.

Apparatus for blowing bottles. ÉMILE ROIRANT (Soc. anon. d'études et de constructions d'appareils mécaniques pour la verrerie). U. S. 1,946,411, Feb. 6, 1934.

Glassware conveyer. E. G. BRIDGES (Lynch Corp.). U. S. 1,946,452, Feb. 6, 1934.

Glass polishing tool. F. B. WALDRON (Pilkington Bros., Ltd.). U. S. 1,946,955, Feb. 13, 1934.

Method and apparatus for annealing glassware. H. L. EASTMAN (Hartford-Empire Co.). U. S. 1,947,408, Feb. 13, 1934.

System for tempering glass, etc., through hot-air suction. L. MOSMIERI. Brit. 403,438, Jan. 3, 1934.

Glassmelting furnaces. PATENT-TREUHAND-GES. FÜR ELEKTRISCHE GLÜHLAMPEN M.B.H. Brit. 403,572, Jan. 3, 1934.

Manufacture of laminated nonsplintering glass. A. RENFREW, J. S. B. FLEMING, AND IMPERIAL CHEMICAL INDUSTRIES, LTD. Brit. 403,723, Jan. 10, 1934.

Process and apparatus for finishing fused silica articles. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY ET CIREY. Brit. 403,898, Jan. 10, 1934.

Tools and appliances for working glass and other vitreous substances in liquid or plastic state. Z. VERESS, JR., AND E. KOVACS. Brit. 403,938, Jan. 17, 1934.

Machines for pressing and molding articles of glass. W. B. MITCHELL. Brit. 403,983, Jan. 17, 1934.

Apparatus for forming glassware. BRITISH HARTFORD-FAIRMONT SYNDICATE, LTD. Brit. 404,238, Jan. 17, 1934.

Mechanical manufacture of glass bottles with precisely dimensioned neck openings. J. MAREK AND E. KOVACS. Brit. 404,308, Jan. 24, 1934.

Front glasses for vehicle head lamps. TALBOT ANTI-DAZZLE CONE, LTD., AND S. E. TALBOT. Brit. 404,343, Jan. 24, 1934.

Production of nonsplintering glass plates. F. MEYER. Brit. 404,352, Jan. 24, 1934.

Manufacture of hollow glass bodies. P. NOEL. Brit. 404,465, Jan. 24, 1934.

Making of glass and electric furnaces therefor. HARTFORD-EMPIRE CO. Brit. 404,733, Jan. 31, 1934.

Method and machine for forming ribbons of glass having spaced bosses thereon. CORNING GLASS WORKS. Brit. 404,913, Jan. 31, 1934.

Manufacture of glass vessels from tubing. J. DICHTER. Brit. 404,916, Jan. 31, 1934.

Glass tanks. SIMPLEX ENGINEERING CO. Brit. 404,934, Feb. 7, 1934.

Method and apparatus for making glass. SIMPLEX ENGINEERING CO. Brit. 405,012, Feb. 7, 1934.

Apparatus for handling and trimming glass sheets in sheet-drawing apparatus. NAAMLOOZE VENNOOTSCHAP HOLLANDSCHE MAATSCHAPPIJ VOOR DE VERVAARDIGING VAN GLAS. Brit. 405,181, Feb. 7, 1934.

Structural Clay Products

Strength, water absorption, and weather resistance of building brick produced in the United States. J. W. McBurney and C. E. Lovewell. *Proc. A.S.T.M.*, **33** [Part I], 636–50 (1933).—This paper reports averages and distribution for flat compressive strength, modulus of rupture, and water absorption by 3 methods for brick samples from 255 plants whose output represented 37% of the 1929 brick production of the U. S. The following conclusions are presented: (1) The weighted averages for all samples are flat compressive strength 7246 lb./in.², modulus of rupture 1154 lb./in.², water absorption 5 hr. cold 10.12%, 48 hr. cold 10.92%, 5 hr. boiling water 13.99%, and a ratio of 48 hr. cold to 5 hr. boiling water 0.764%. (2) The weighted averages for all samples classified by the manufacturers as hard are flat compressive strength 7434 lb./in.², modulus of rupture 1183 lb./in.², water absorption 5 hr. cold 9.77%, 48 hr. cold 10.56%, 5 hr. boiling water 13.66%, and a ratio of 48 hr. cold to 5 hr. boiling water 0.758%. (3) The weighted averages for all samples classified by the manufacturers as salmon are flat compressive strength 4094 lb./in.², modulus of rupture 678 lb./in.², water absorption 5 hr. cold 15.94%, 48 hr. cold 16.77%, 5 hr. boiling water 19.41%, and a ratio of 48 hr. cold to 5 hr. boiling water 0.851%. (4) For the U. S. as a whole the range in compressive strength is from less than 1500 lb./in.² to over 21,000 lb./in.² and the range in 5 hr. boiling water absorption is from less than 2 to 34%. (5) Shale brick have a narrower range for all properties than clay brick. (6) No single measure of strength or water absorption will sharply separate salmon from hard brick where both clay and shale samples are considered together. (7) Shale brick can be sharply separated into hard and salmon by requiring a compressive strength of not less than 7500 lb./in.², a modulus of rupture of not less than 1200 lb./in.², or water absorption of not more than 10% cold or 12% boiling water. (8) The combination, not less than 2500 lb./in.² compressive strength with an absorption of not more than 0.80% or a compressive strength of not less than 6000 lb./in.² with an absorption ratio of not more than 0.85, insures resistance to 51 cycles of freezing and thawing. (9) The combination, not more than 18% water absorption by 5 hr. boiling water with an absorption ratio of not more than 0.80% or a water absorption of not more than 12% by 5 hr. boiling with an absorption ratio not exceeding 0.85, insures resistance to 51 cycles of freezing and thawing. R.A.H.

Permeability of brick masonry walls—a hypothesis. W. C. Voss. *Proc. A.S.T.M.*, **33** [Part I], 670–91 (1933).—When a brick wall permits rain to penetrate, there is an error in the selection of materials, the design of the wall, the workmanship, or a combination of these factors. The selection of a dense brick and a dense mortar does not necessarily solve the problem. If a wall leaks due to poorly selected materials it is because the brick has separated from the mortar and the water passes through these minute cracks. A thorough study of the properties of a brick to produce the best results seems to indicate that a brick should absorb from 5 to 10% of its weight in water in 2 days; the water should be absorbed at a low rate after the first 10 or 15 min. This permits the mortar to build up a "bond layer" at the brick line which will insure no separation at that point. Lime is required to supply the materials necessary for this action, and the best mortar for general use with good brick is composed of 1 part of Portland cement, 1 of lime, and from 5 to 6 of sand by volume. R.A.H.

Research work in impervious brick masonry. J. F. Nichol. *Canadian Eng.*, **66** [4], 7–8 (1934).—To successfully exclude water or moisture from masonry, good design, workmanship, and materials are essential. These points are explained in detail. The general mortar-mix recommendations to obtain good masonry for each kind of brick are as follows, assuming average temperature conditions (about 60°F) and average joint thickness (about $\frac{1}{2}$ inch): (1) for dense brick (up to about 5% absorption), a mix of 1:$\frac{1}{2}$:4$\frac{1}{2}$, cement, dry high-magnesium hydrated lime, loose moist sand by volume; (2) for brick of medium absorption (from about 5 to 10% absorption) a mix of 1:1:6 cement, lime putty, loose moist sand by volume; (3) for highly absorbent brick (from about 10 to 15% absorption), a mix of 1:2:9, cement, high-calcium 7-day lime putty, loose moist sand by volume. The basic premise in specifying these mixes is that as the absorption of the brick or the average temperature increases or as the average joint thickness decreases, the water-retaining capacity of the mortar must increase, or conversely. This is obtained by increasing the ratio of lime to cement and by using soaked lime putty instead of dry hydrate. E.J.V.

Application of thermocouples to measurement of wall-surface temperatures. A. P. Kratz and E. L. Broderick. *Heating & Ventilating*, **30** [5], 40 (1933).—As the real surface temperature of the wall is desirable in laboratory temperature measurements of the heat flow between walls and air, a test apparatus was set up to determine the best method to use. Establishment of a temperature gradient at a position close to the wall surface was provided. This gradient, extended to the wall surface, established the true surface temperature which could be compared with values indicated by various thermocouples attached to the wall surface. If the gradient showed the true temperature, the error in the readings of the other couples could be found. A couple made of fine wire (No. 34 B & S) having the junction and 3 in. of the leads imbedded in the surface and sealed flush with plaster of Paris or cement showed the true surface temperature for all practical purposes. E.J.V.

Thermal properties of building materials. F. B. Rowley and A. B. Algren. *Heating & Ventilating*, **29** [9], 50 (1932).—Tests on building walls are reported in terms of the overall transmission coefficient. Some tests were made by the hot-box method; other results were calculated from coefficients previously obtained and checked against the overall test figures. Tests were made on walls of clay tile, concrete, brick, and rubble. The variation of the coefficient with the mean temperature was plotted for a number of wall constructions under several mean temperatures. The coefficients increase with the temperature. E.J.V.

Fundamentals and economies in the clay industries. No. 33. ELLIS LOVEJOY. *Clay-Worker*, **100** [6], 194–95 (1933).—L. describes salt glazing and its related problems such as slabbing, blisters, cracking, and crazing. Under salting he describes sulfur and scum effects, kind and quantity of salt, the kiln, and firing methods. For No. 32 see this issue, p. 97. A.J.M.

Practical clayworking. IX. ANON. *Brit. Clayworker*, **42** [501], 292–93 (1934).—The semidry process of manufacturing brick is discussed. The piano-wire, rotary, and mechanically or electrically vibrated screens are described. A description of the manufacture of roofing tile by the hand-made process is included. R.A.H.

Effect of de-airing clay bodies by evacuation. J. W. AKAM. *Brit. Clayworker*, **42** [500], 273–74 (1933).—After discussing the results of tests at Ohio State University, A. summarizes the results of de-airing in terms of its benefit to the manufacturer of clay products. It is found (1) that conditions are so improved at the point of extrusion that interruption in the continuity of a column of good ware is reduced, (2) that increased plastic strength will reduce loss through damage to green ware in handling, and (3) that these factors should increase the output of the auger machine to the drier over a day's operation. The ware produced should be improved in quality and it is expected that some shapes can be manufactured with present raw materials which previously could not be formed. No saving can be expected in the drying operation or in fuel consumption and kiln turnover in the firing operation, but the kiln should produce a better quality ware. R.A.H.

Sewer pipe and its problems. WALTER A. HULL. *Brick Clay Rec.*, **84** [1], 23–24 (1934).—The failure of manufacturers to ask machinery men to supply new ideas is the reason why the sewer-pipe industry has remained in a business rut. This article is a discussion on the subject which was abstracted in *Ceram. Abs.*, **13** [3], 61 (1934). E.J.V.

Suitability of limes for sand-lime brick manufacture. G. E. BESSEY AND H. J. ELDRIDGE. *Jour. Soc. Chem. Ind.* [London], **52** [51], 443–47*T* (1933).—Lime samples of a wide range in composition and quality were examined for sand-lime brick suitability. The property of chief importance is soundness. A soundness test is described and permissible limits of expansion are suggested. Magnesian limes require careful treatment and except under exceptional circumstances should be avoided. A.J.M.

Brick walls with a new unit shape. A. W. KEICHLINE. *Architecture*, **65** [2], 108 (1932).—A new unit for making 8-in. walls without through mortar joints, having the weight of a common brick but a volume of 2 brick with webs between 2 faces of standard brick size, is described and some of its advantages from an architectural and labor-saving standpoint are enumerated. Illustrated. See also *Ceram. Abs.*, **11** [9], 490 (1932). E.J.V.

Tests on brick masonry beams. M. O. WITHEY. *Proc. A.S.T.M.*, **33** [Part I], 651–69 (1933).—Data are given on shear and bending strengths of twenty-five 8- by 12-in. reinforced brick beams tested under third-point loading over an 8-ft. span. Three widely different varieties of brick and several variations in percentage of longitudinal steel between 0.5 and 2.3% as well as different percentages of stirrup reinforcement were used. The tests indicate that a high degree of flexural and shear strength can be developed in reinforced brick beams provided due attention is paid to mortar bond, coursing, amount and arrangement of reinforcement, and filling of joints. Formulas for reinforced concrete design with appropriate constants can be used to calculate stresses and deflections of reinforced brick beams. R.A.H.

Reinforced brick masonry fence. JUDSON VOGDES. *Clay-Worker*, **100** [5], 154–55 (1933).—Illustrated. A.J.M.

Reinforced brick masonry barn. JUDSON VOGDES. *Clay-Worker*, **100** [6], 196–97 (1933).—Illustrated. A.J.M.

Ten dollars per manufacturer will give brick one of its greatest boosts. E. F. GALLAGHER. *Brick Clay Rec.*, **84** [1], 22 (1934).—A demonstration of the value of reinforced brick masonry before the leading builders of the country at Boston in April, 1934, by the use of test structures to be paid for by contributions from the brick manufacturers is proposed. E.J.V.

Properties of Ambrož wedge-shaped hollow ceiling tile and ceiling structures. O. KALLAUNER AND J. MATĚJKA. *Stavivo*, p. 21 (1933).—The wedge-shaped hollow ceiling tile invented by K. Ambrož have proved successful. R.B.

Auger of the brickmakers' auger machine. A. REZÁČ. *Stavivo*, p. 19 (1933).—Best efficiency is obtained by leaving a space between the auger and the barrel to prevent the column of pugged clay from turning with the auger. With thin-walled hollow tile better extrusion is obtained if two augers with double blades are placed between the machine and the die. In one case two feeders were more efficient with low operating speed as they were overdimensioned and high speed caused obstruction in the auger. Structural defects of the ware caused by the auger machine can not be entirely eliminated but they may be greatly reduced. R.B.

Brickworks of Chagny at Burgundy. B. HELAN. *Stavivo*, p. 55 (1933).—From a comparison of kiln efficiencies in brickworks, H. concludes that Czechoslovakian kilns are more efficient than French kilns. In France the modern principles of firing are often neglected, the progress of fire is slow in most cases, density of setting for special tile, expressed in kg./m.^{3}, is very low, tile are set in protective boxing, etc. Much may be learned from French brickworks, however, in the production of thin-walled ware, *e.g.*, roofing tile. The plant at Chagny is described. R.B.

Brickmakers' education. A. REZÁČ. *Stavivo*, p. 4 (1933).—The boundary between theoretical and practical instruction is discussed. R.B.

Modern spirit enters contemporary church architecture. JOSEPH HUDNUT. *Amer. Architect*, **142** [2614], 12–17 (1932).—The newer style of church architecture, in which brick is used to a great extent as the building medium, is discussed at length. Illustrated. E.J.V.

Special features in English brickwork. GERALD K. GEERLINGS. *Architecture*, **65** [2], 91–94 (1932).—A description of the treatment of brick in various bonds and decorative effects seen in England is presented. Illustrated. E.J.V.

BOOK AND BULLETINS

Manual of Structural Design. JACK SINGLETON. H. M. Ives & Sons, Topeka, Kansas. 196 pp. Price $4.50. Reviewed in *Canadian Eng.*, **66** [5], 30 (1934).—This volume combines all the data required by the designer in using reinforced concrete, structural steel, or timber construction. Twenty-four universal beam tables are given which cover a wide range of concrete and steel stresses, each giving resisting moments for rectangular and T-beams with depths from 1 to 64 in. Other tables on concrete include universal stirrup tables, universal load tables for slabs, concrete joists, and clay tile. Other data are included. E.J.V.

Performance characteristics of reinforced brick masonry slabs. II. JOHN W. WHITTEMORE AND PAUL S. DEAR. *Virginia Polytech. Inst. Eng. Expt. Sta. Bull.*, No. 15, 45 pp. (Nov., 1933).—To substantiate the conclusion made in a previous report that reinforced brick masonry slabs perform in a manner similar to reinforced concrete slabs, four concrete slabs identical in construction and preparation were tested and the results were compared. It was concluded that for well past design loads (1) relations of load to deflection and stress are linear, (2) both possess ample stiffness, (3) both exhibit ample safety factors, (4) their performance characteristics are in close agreement, and (5) the same design formulas are adaptable to each. For Part I see *Ceram. Abs.*, **11** [11], 570 (1932).

Heat transmission through building materials. F. B. ROWLEY AND A. B. ALGREN. *Univ. of Minnesota Eng. Expt. Sta. Bull.*, No. 9. 106 pp. Reviewed in *Heating & Ventilating*, **30** [2], [illegible] (1933).—Data from tests using three sets of apparatus are given, (1) for hot-plate conductivity determinations, (2) a hot-box method for overall transmissions, and (3) a fan set-up for surface-coefficient determination. The method of application of insulating materials has a decided effect on heat transmission through some constructions. E.J.V.

PATENTS

Clay product and method of making. HERMAN REISER. U. S. 1,945,232, Jan. 30, 1934. This process of making a clay product consists in mixing brick or potters clay with the residuum obtained by burning rice hulls.

Truss tile. A. H. FARRENS. U. S. 1,945,681, Feb. 6, 1934.

Interlocking brick-block construction. F. E. CLARK. U. S. 1,947,188, Feb. 13, 1934.

Method and means for separating machine-made severed wire-cut brick for facility of drying. H. H. BAILEY AND J. JACKSON. Brit. 404,760, Jan. 31, 1934.

Refractories

Measurement of reaction rates at high temperatures. J. H. CHESTERS AND C. W. PARMELEE. *Jour. Amer. Ceram. Soc.*, **17** [3], 50–59 (1934).

Measuring thermal conductivity of refractory materials and insulators. L. LONGCHAMBON. *Céramique*, **36** [546], 215–17 (1933).—L. gives a method for determining the thermal conductivity of refractories by determining isothermal surfaces in the refractory and measuring the quantity of heat which traverses these surfaces. M.H.B.

Permeability to water and saturation of refractory materials. OTTO BARTSCH. *Ber. deut. keram. Ges.*, **14** [11], 471–84 (1933).—A method for measuring the speed of saturation is presented. The quotient of the time (T_{20}) which a solution requires to rise to a definite height and the amount of liquid (V_{20}) absorbed within this time is designated as the "saturation resistance value." No close connection exists between the permeability to water and the amount of liquid absorbed in saturation. However, there is a far-reaching parallelism between speed of saturation ($1/T_{20}$) and permeability to water (DW). Exceptions can be explained by fundamental differences in the pore structure which can be traced to some other sort of filling of the pore space, according to which the saturation results only through the capillary ascension or through additional external pressure. The relation between the two quantities can be expressed by the equation, $1/T_{20} = k(DW)^n$. The pore size can not be determined from the speed of saturation of the investigated bodies, as the pores are only partially filled with water on account of the formation of capillary pockets. Herein exists the possibility of preference of a wholly fixed pore size (selective capillary pocket blockade). The use of this method for determining the resistance to saturation is recommended if a saturation results only by a capillary ascension. It can not be replaced by the measurement of permeability to water and the absorption of glycerine without additional data. E.J.V.

Relationship between water permeability and structure of refractory materials. OTTO BARTSCH. *Tonind.-Ztg.*, **57** [98], 1158–59; [100], 1182–83 (1933).—After discussing the importance of determining the pore size and permeability as means for investigating the structure of refractories, B. describes experiments made to ascertain the effect of the firing temperature, prefiring of grog, distribution of grains in the grog, and methods of manufacturing on the water permeability. Tables and diagrams show that permeability varies in a different manner than the temperature. Pore dimensions are therefore related to porosity. The effect of the powder content of the refractory is very great; permeability decreases with an increasing powder content. No relationship between porosity and permeability was found. The afterpressing of molded and dried mixes produced the lowest figures of permeability, but in cast mixes it depends on the composition of the bonding clay. M.V.K.

Calculating the resistance to temperature changes of refractory brick according to their physical constants. K. ENDELL. *Glastech. Ber.*, **11** [5], 178–82 (1933); abstracted in *Chim. & ind.*, **30** [5], 1113 (1933).—The resistance to temperature changes of refractories is poorly defined and is evaluated by the number of quenchings in water of a brick after heating to 950° until the appearance of the first fissure. Two formulas based on the mechanical and thermal characteristics of refractories are used for measuring this property scientifically, (1) that of Winkelmann and Schott based on the resistance and the

coefficient of elasticity or of compression, and (2) that of Norton, based on the resistance and the coefficient of elasticity of torsion. According to experiments made with different refractories to determine whether a relationship exists between the resistance calculated according to the two formulas and the number of quenchings, it was found that there is no relationship between this number and the resistance calculated according to the first formula; by using the formula of Norton, the curve obtained has the appearance of a geometrical figure. M.V.K.

Making refractories by fusion. ANON. *Brit. Clayworker*, **42** [500], 266–67 (1933).—A discussion is given on refractories made from previously fused material such as fused silica, electrically fused magnesia, silicon carbide, and mullite. Articles made from fused materials have exceptional density, uniformity of texture, and resistance to abrasion and corrosion. R.A.H.

Making refractories by a cold process. ANON. *Eng. Progress*, **14** [11], 222 (1933).—By the use of patented "Delta" cement, refractory brick can be produced by air drying without a firing treatment. Refractory ingredients such as fire clay, Dinas clay, magnesite, or chromite are intimately mixed with the cement. The mixture is matured in a pit by a wetting process which requires about 2 weeks and the brick are formed by hand or by machinery. After drying for 8 or 10 days in dry rooms or in open air they are ready for use. There is no appreciable volume change in drying. The equipment required to make these brick is a mixer, a concrete pit, and a brick press. Delta stones have been used with satisfactory results as linings for foundry ladles, melting furnaces, cement kilns, steam-boiler furnaces, etc. The material does not soften up to temperatures of 1750 to 1770°C (3200 to 3500°F); the mechanical strength is about the same as that of fired refractories. J.L.G.

Testing refractories. CHARLES MEURICE. *Rev. mat. constr. trav. pub.*, No. 288, pp. 163–67*B*; No. 289, pp. 186–88*B*; No. 290, pp. 203–205*B* (1933); for abstract see *Ceram. Abs.*, **11** [1], 34 (1932). M.V.K.

Elimination of load failures of refractories. F. H. NORTON. *Fuels & Fur.*, **11** [6], 206–10 (1933).—The load-bearing properties of the various kinds of refractories are discussed. Methods of testing and improving these properties are listed. Types of load failures in service and furnace construction to minimize them are described. E.J.V.

Graphite, a refractory building material. ERICH BUCHHOLTZ. *Tonind.-Ztg.*, **57** [102], 1207–1208 (1933).—After reviewing the refractory materials employed for crucibles and furnace linings, B. discusses (1) the properties and advantages of graphite as a refractory, (2) manufacture of graphite crucibles, (3) kinds of graphite, and (4) German and foreign graphite deposits. M.V.K.

Formation of SiC. KURT ARNDT AND EWALD HAUSMANN. *Z. anorg. allgem. Chem.*, **215** [1], 66–74 (1933).—A study of the formation of silicon carbide with special emphasis on the influence of the type of raw material is presented. The raw materials used include quartz sand and anthracite or wood charcoal or petroleum coke. The rate of formation of SiC was determined at various temperatures. The authors found no traces of the spurious siloxicon, Si_2C_2O. L.T.B.

Alundum C. F. aggregate. ANON. *Chem. Met. Eng.*, **40** [7], 375 (1933).—Norton Company has developed a new grade of Alundum aggregate, designated as C. F. A.K.

Chrome cements. MAURICE BARRETT. *Brit. Clayworker*, **42** [501], 294 (1934).—The basic constituent of these cements is natural chrome ore, which is a chemical compound of the two metals, chromium and iron. In general, the higher the percentage of chromium oxide in a sample, the more valuable is the mineral for refractory purposes. The physical structure of the selected ore should be hard and dense, the friable and crumbly varieties being quite useless for the purpose under consideration. The fusing point of suitable material should not be below 2000°C. Chrome is characterized by its inertness, but at very high temperatures it combines with carbon, forming an alloy of iron, chromium, and carbon. Alkalis and lime at high temperatures and under oxidizing conditions attack it with the formation of chromates. Although in the modern method of manufacturing chrome shapes no bond is used, for cements an artificial bond is essential. Among the bonds tried or in use are talc, soapstone, ball clay, kaolin, fire clay, plaster of Paris, bauxite, magnesite, dolomite, some alkaline salts, and various organic bonds such as tar, resin, and gum. Electrically fused chrome ore has been placed on the market recently. Proper grading of the ore is vital, a standard No. 40 sieve being recommended for passage of the ore. Examples of cements are as follows: (1) cement *A:* chrome ore through No. 40 sieve 128 weight units, bentonite 6 weight units, gum arabic 1 weight unit, minimum of water used for mixing to stiff consistency; (2) cement *B:* chrome ore through No. 40 sieve 100 units, chrome alum powdered 3 units, bentonite 2 units, gum arabic 2 units, mixed with hot water; and (3) cement *C:* chrome ore 80 units and sodium silicate powder 8 units. In cement *C* liquid sodium silicate may be used in place of powder. R.A.H.

Chrome ore deposit in Philippine Islands. ANON. *Chem. Met. Eng.*, **40** [10], 548 (1933).—Preparations are being made to work an extensive and rich deposit of chromite ore recently discovered in the Philippine Islands. The deposit is estimated to contain approximately 50,000 tons, analyzing about 50% chromic oxide and 15% iron oxide. A.K.

Magnesite bonding mortar. HARBISON-WALKER REFRACTORIES CO. *Blast Fur. Steel Plant*, **22** [1], 49 (1934).—A new bonding mortar based on a grain magnesite having a low percentage of impurities with a balanced series of bonding constituents to give strength over a range of temperatures from cold to operating temperatures has been developed. H-W 290 bonding mortar is highly refractory and may be used at all temperatures at which magnesite brick can be used. E.J.V.

Magnesite lining. ANON. *Rock Products*, **37** [1], 85 (1934).—Using Ritex in the hot zone of a Mexican cement kiln, the previous plant record has been exceeded 2.4 times with no failure of the lining noted. In New England a 15-ft. hot zone lining of Ritex gave 310 days' life as against a previous average of 54 days on brick linings. Ritex differs considerably from regular fired magnesite brick, especially in the matter of spalling resistance. Illustrated. E.J.V.

Magnesite brick for glass tank checkers. GENERAL REFRACTORIES CO. *Fuels & Fur.*, **11** [6], 231 (1933).—Tests on the hydraulically compressed, chemically bonded, unfired magnesite brick known as Ritex show that this brick was unaffected by the attack due to fluxes carried over in the checker chamber even after a period of five months, while silica brick lost 30% of its volume in the same period. E.J.V.

Brick of coke-oven walls. T. KURODA. *Jour. Soc. Chem. Ind.* [Japan], **36** [12], 655–56*B* (1933).—Changes in the chemical composition of silica brick from coke ovens caused by long exposure to high temperature were studied. The face of the brick which was in contact with coal had a higher Fe content, while the brick facing the flue side had a lower Fe_2O_3 and Fe content due to the fact that the iron oxide, exposed to a reducing flame, is converted into metallic iron which diffuses into the brick. M.V.K.

Refractory brick for Cowper apparatus. R. LEDUC. *Céramique*, **36** [548], 260–67 (1933).—L. finds the following characteristics essential in refractories for use in blast-furnace stoves: (1) a large amount of active refractory surface, (2) fusion point well above the operating temperature of 1400°C, (3) good load-bearing qualities at high temperatures, (4) high coefficient of heat conductivity, (5) low coefficient of expansion, and (6) resistance to chemical attack of the gases. High alumina fire clay is used almost entirely. Clay-coated silicon carbide is excellent except for its excessive cost. M.H.B.

Features of modern furnace practice. ANON. *Power Plant Eng.*, **38** [1], 28–33 (1934).—Heat-release values used will be dictated by the type of furnace walls used. Solid refractory walls are suitable and are the most economical for furnaces which operate below 150% rating. Between 150 and 250% some form of air-cooled wall is advisable and in general above 250% the water-cooled wall is the most economical. A detailed discussion of the construction of solid refractory walls, insulation thereof, air-cooled walls, water-cooled walls, and arches is presented. Illustrated. E.J.V.

Boiler furnace refractories: Physical and chemical factors affecting the life of refractories. F. J. MATTHEWS. *Power Engineer*, **28** [3], 86; [4], 126; [5], 158 (1933); abstracted in *Fuel Sci. Practice*, **12** [7], 254 (1933). F.G.H.

Rational lining for boilers. A. BACHMAIR. *Arch. Wärmewirtschaft*, **14** [7], 175–78 (1933); abstracted in *Chim. & ind.*, **30** [6], 1322 (1933).—The chief properties of refractory materials employed for boilers are (1) resistance to temperature changes, compression, and slagging, (2) invariable volume in service, and (3) mechanical resistance. The attack on the linings is of a chemical and physical nature. The resistance of a lining depends on the nature of fuel, slag produced, and chemical composition of the refractory. The best protection for refractory masonry consists in cooling the walls by circulating water. The temperature of the brick must be always lower than the softening temperature and the fusion point of the slag. M.V.K.

Determination of porosity of grog mixes. M. A. BESBORODOV. *Keram. Rund.*, **41** [38], 498–500 (1933).—An account is given of experiments made to determine the most rapid method for ascertaining the porosity of grog masses. The vacuum method with boiling was found to be the best. The dependence of the change in porosity on the duration of the vacuum test was also studied. Tables and diagrams illustrate the paper. For original reference see *Ceram. Abs.*, **12** [1], 29 (1933). M.V.K.

Sagger problems; ways to solve them. ANON. *Ceram. Ind.*, **22** [2], 89–93 (1934).—Ideas which have been proposed for saggers and sagger materials are coördinated and reviewed. E.J.V.

Review of gasworks practice, 1932. H. D. GREENWOOD. *Fuel Econ. Rev.*, **12**, 12–20 (1933).—Further work has been carried out by the Refractory Materials Sub-Committee of the Institution of Gas Engineers on three problems as follows: (1) permeability of refractory materials to gases (*Ceram. Abs.*, **13** [3], 63 (1934)), (2) action of carbon monoxide on refractory materials (*ibid.*), and (3) hot patching of gas retorts. Reference is made to a simple apparatus for determining the heat-insulating properties of brick and an apparatus for observing the behavior of refractory materials under torsion. A vertical retort of silica brick gave 40% greater throughput than a similar retort of fire brick, owing to greater thermal conductivity and crushing strength of the silica brick. W.E.R.

BULLETINS

Outline of the manufacture and properties of stiff-mud fire brick. E. H. VAN SCHOICK. *Amer. Refrac. Inst. Tech. Bull.*, No. 45, 8 pp. (1933). 4 figs. A typical flow diagram for the manufacture of stiff-mud fire brick is presented, together with brief descriptions of the processes and equipment used. A table gives the properties of 27 samples of fire brick made by the stiff-mud process. W.E.R.

Silica, slag, and slagging. J. G. STEIN AND CO. Reviewed in *Fuel Economist*, **8** [93], 539 (1933).—This bulletin includes a table giving the melting points for some of the common oxides with the corresponding silicates and low melting eutectic temperatures. Illustrations of sections through silica brick showing the attack of specific agents submitted to a temperature of 1460°C are given. M.V.K.

Chromite. L. A. SMITH. *Bur. Mines Minerals Yearbook*, 1932–1933. Separate chapter, 10 pp., price 5¢. R.A.H.

Water-gas generator furnace linings. MCLEOD AND HENRY CO. *Power*, **77** [12], 666 (1933).—*Bulletin* No. G-164 describes how to line water-gas generator furnaces with refractory linings. F.G.H.

PATENTS

Lightweight ceramic material and method of making. F. B. HOBART (Battelle Memorial Institute). U. S. 1,944,007, Jan. 16, 1934. A method of making lightweight porous ceramic material comprises mixing clay, etc., with a soluble silicate solution, foaming the mixture, and introducing a chemical to bring about gelation thereof.

Heat insulating material and method of making. F. B. HOBART (Battelle Memorial Institute). U. S. 1,944,008, Jan. 16, 1934. A method of making heat-insulating material comprises producing a foam from a soluble silicate solution and mixing a filler with the foam.

Refractory lining for crucibles. HERMANN SCHULTZ. U. S. 1,944,278, Jan. 23, 1934. A lining for crucibles comprises refractory frusto-conical rings adapted to be superposed to form a hollow frusto-conical body and to be nested to form a frusto-conical disk.

Process of obtaining aluminum oxide. STEPHEN HUNYADY. U. S. 1,944,327, Jan. 23, 1934.

Water-cooled furnace wall. OSCAR NYGAARD. U. S. 1,944,569, Jan. 23, 1934.

Process for making cast compact ceramic products. VLADIMIR ŠKOLA (Corning Glass Works). U. S. 1,944,616, Jan. 23, 1934. In casting refractory articles from a melt of highly aluminous materials, the steps of maintaining the melt in a liquid state while the metallic impurities settle to the bottom and imperfectly melted particles rise to the top and of casting the articles from the intermediate layer of the melt are described.

Refractory body and process of manufacturing. KONRAD FRIEDERSDORFF (Stellawerk A.-G., vorm. Wilisch & Co.). U. S. 1,944,709, Jan. 23, 1934. The method of manufacturing refractory bodies consists in first making a composition of a base material in the form of coarse grains of similar size, grains of smaller size, the size and amount of the smaller grains being such that they are adapted to fill out the interstices between the coarser grains without forcing them apart, and matter smaller in size than the smaller grains and having a size such that it is adapted to fill out the interstices between the grains of larger and smaller size, adding pieces of stable matter larger in size than the coarse grains, and manufacturing bodies from the composition.

Glass-resistant refractory and batch composition for producing it. P. G. WILLETTS (Hartford-Empire Co.). U. S. 1,944,856, Jan. 23, 1934. A batch for a ceramic refractory resistant to molten glass comprises approximately 65 parts by weight of homogeneous granules of grog containing derivatives of approximately 92.5% of a mixture of Georgia Klondike kaolin and Georgia G_1 clay and approximately 7.5% Bedford feldspar fired to a temperature of approximately 2850°F and having substantially the same physical and chemical characteristics as the refractory to be produced, and approximately 35 parts by weight raw binding material composed of approximately 92.5% of a mixture of Georgia Klondike kaolin and Georgia G_1 clay and approximately 7.5% Bedford feldspar, both the mixture and the feldspar being substantially the same as the mixture and feldspar from which the grog is derived.

Silica brick. JULIUS SCHÜFFLER (Koppers Co. of Delaware). U. S. 1,945,236, Jan. 30, 1934.

Furnace wall. J. M. LAMBIE (Findlay Clay Products Co.). U. S. 1,946,083, Feb. 6, 1934.

Liner block for tubular fluid-cooled walls. J. S. BENNETT (American Engineering Co.). U. S. 1,946,125, Feb. 6, 1934.

Manufacture of porous bodies comprising refractory granules and a ceramic bond. W. W. TRIGGS (Norton Co.). Brit. 404,306, Jan. 24, 1934.

Production and application of refractory blocks and masses resisting destruction by carbon. VEREINIGTE STAHLWERKE AKT.-GES. Brit. 404,699, Jan. 31, 1934.

Terra Cotta

Relations of stone structure and strength. H. BUCHARTZ, G. SAENGER, AND K. STÖCKE. *V.D.I. Forschungscheft*, p. 358; *Pit & Quarry*, **26** [2], 44 (1933).—Differences in resistance to impact are explained by differences in structure revealed by petrographic description. It was concluded that the Föppl ramming test widely used in Germany for evaluating stone is an adequate measure of the stone's utility. The impact-bending test can also be adapted from ceramics if large enough test specimens are used. E.J.V.

Practical observations on the relationship between fissures due to firing and clay analysis. W. SCHUEN. *Tonind.-Ztg.*, **57** [97], 1146–47 (1933).—After discussing the cracking of stoneware objects on firing, S. states that the less salt (silicate) the clay substance contains and the more acid present in it, the more often the fissures appear; the more acid the clay substance, the more this defect is increased. The acid formulas of the clay substance of a number of known clays calculated according to analyses are given in a table. Illustrated. M.V.K.

Technical study and practice of mixing and preparing ceramic stoneware slips. FELIX CHALAMEL. *Céramique*, **36** [547], 235–46 (1933).—C. describes a series of investigations on the preparation of stoneware slips. Results were obtained by the following methods: (*a*) levigation, (*b*) determination of plasticity, cohesion, and deformation, (*c*) microscopic examination of fired and unfired products, and (*d*) determination of physical properties such as porosity, resistance to compression, and torsion. Six conclusions are given. (1) Fineness of grinding and sharp grains favor homogeneity, plasticity, and cohesion, diminish porosity and deformation in firing, and augment the resistance to compression and torsion. (2) The best mixtures have a vitrifiable clay base and an addition of fusible feldspathic rock. (3) Semiwet mixing with the addition of feldspar ground to 200-mesh and clay ground to 20-mesh gives regular fired products which are free from cracks and nonporous and have excellent physical properties. (4) Imperfect moistening of the mix leads to many difficulties. (5) Storing the slip facilitates pressing and aids in obtaining regular shapes. (6) Firing in the tunnel kiln gives harder fired products. M.H.B.

Acid-proof, stoneware-lined centrifugal pumps. UNITED STATES STONEWARE CO. *Platers' Guide*, **30** [1], 16 (1934).—A new series of stoneware-lined centrifugal pumps for handling corrosive substances combines features of compactness, semi-automatic gland adjustment, dual impeller, easy accessibility and standardization of all parts, ground stoneware parts, all metal parts of corrosion-resisting alloys, Timken bearings, and efficiency equal to all-metal water pumps of similar size in pumping acids, alkalis, and corrosives except hydrofluoric acid. Illustrated. E.J.V.

British chemical stoneware. G. N. HODSON. *Chem. &*

Ind., **52** [49], 986–90 (1933); for abstract see *Ceram. Abs.*, **13** [3], 65 (1934). A.J.M.

Craftsmanship in chemical stoneware. THEODORE R. OLIVE. *Chem. Met. Eng.*, **40** [7], 369–71 (1933).—O. describes the manufacture of intricate types of chemical stoneware at the Maurice A. Knight plant, Akron, Ohio. A.K.

Making terra cotta. F. S. LINCOLN. *Architecture*, **67** [4], 207–10 (1933).—A pictorial review of the main operations in the production of terra cotta at the Perth Amboy, N. J., plant of the Atlantic Terra Cotta Co. is presented. Illustrated. E.J.V.

Craftsmanship in tile. EUGENE CLUTE. *Architecture*, **66** [4], 187–92 (1932).—Types of tile being produced for use in fine architecture are described. Novel floor, wall, and pictorial treatments possible with tile are described. Illustrated. E.J.V.

PATENTS

Roofing tile. LUDOWICI KOMM.-GES. AUF C. AKTIEN. Brit. 405,126, Feb. 7, 1934. C. BOULANGER. Brit. 405,-136, Feb. 7, 1934.

White Wares

Study of frit compositions. C. W. PARMELEE AND K. C. LYON. *Jour. Amer. Ceram. Soc.*, **17** [3], 60–66 (1934).

Microstructure of mat lead glazes. C. W. PARMELEE AND WILLIAM HORAK. *Jour. Amer. Ceram. Soc.*, **17** [3], 67–72 (1934).

Notes on a continuous electric decorating kiln. J. W. HEPPLEWHITE. *Bull. Amer. Ceram. Soc.*, **13** [2], 44–45 (1934).

Use of galena, natural lead sulfide, in the ceramic industry. MARC LARCHEVÊQUE. *Céramique*, **36** [546], 221–24 (1933).—The use of lead sulfide in ceramic glazes is dangerous due to the solubility of toxic lead salts in dilute acids. Precautions which must be taken to render the glaze as insoluble as possible are discussed. Methods for determining the solubility are given. M.H.B.

Firing hard porcelain in an electric furnace. FR. E. RUSS AND R. BUCHKREMER. *Keram. Rund.*, **41** [35], 457–59 (1933); abstracted in *Chim. & ind.*, **30** [6], 1372 (1933).—An account of researches made on different kinds of porcelain samples is given. The reduction of coloring oxides, particularly iron oxide, is due to a reducing atmosphere containing from 3 to 4% CO. To avoid the precipitation of carbon into the pores of the mix (reversible reaction $2CO \rightleftharpoons C + CO$ occurring between 450 and 1000°), the reducing gas should not be introduced before a temperature of 1000° is reached. When the glaze is melted (between 1200 and 1250°), the composition of the furnace atmosphere has no effect on the porcelain. The necessary maximum temperature is between 1350 and 1420° (Seger cones 12 and 14 to 15). The elimination of saggers shortens the firing time to 10 to 11 hr. instead of the usual 20 to 30 hr. M.V.K.

PATENTS

Oil-bath insulator. ROBERT WEILL. U. S. 1,944,383, Jan. 23, 1934.

Arcing horn for insulators. H. B. VINCENT AND H. P. SLEEMAN (R. Thomas & Sons Co.). U. S. 1,947,321, Feb. 13, 1934.

Closet bowl. R. E. CRANE AND D. E. GULICK. U. S. 1,947,439, Feb. 13, 1934.

Water-closet basins. TWYFORDS, LTD., AND J. T. WEBSTER. Brit. 403,585, Jan. 3, 1934.

Manufacture of jars and bottles of pottery ware. S. M. BUCHAN, C. BUCHAN, AND E. M. BUCHAN (A. W. Buchan & Co.). Brit. 403,748, Jan. 10, 1934.

Method and apparatus for finishing molded clay rings for use as supports for incandescent gas mantles. J. CHRISTIE AND STEATITE & PORCELAIN PRODUCTS, LTD. Brit. 403,969, Jan. 17, 1934.

Electric insulators. W. W. TRIGGS (Ohio Brass Co.). Brit. 404,489, Jan. 24, 1934.

Equipment and Apparatus

High-pressure continuous filter press and press. ROBERT M. THOMPSON. *Bull. Amer. Ceram. Soc.*, **13** [2], 42–43 (1934).

Comments on psychrometric data. FREDERICK G. KEYES AND LEIGHTON B. SMITH. *Heating & Ventilating*, **31** [1], 47 (1934).—Thermodynamic concepts and data pertaining to the properties of mixtures of air and water-vapor have proved to be at variance with actual conditions to such a degree as to affect seriously the accuracy of computations in this branch of air conditioning. The wet-bulb psychrometer is the most practical indicating instrument for air-conditioning work in spite of its inherent inaccuracies resulting from the effects of radiation, variation in velocity of the air stream, temperature effects of impinging air, and the probable limit of the evaporation rate of water. An error of at least −0.3% is reported for the amount of water-vapor in a unit volume of air at atmospheric pressure when computed by the ideal gas law, $PV = wRT$. These discrepancies are indicated by results of experiments on mixtures at high pressure, and the corrections for defects in the ideal gas laws for low pressures are not yet available. The effect of the pressure of the neutral gas in augmenting the vapor pressure is shown to operate as does the ideal gas law defect to increase the amount of vapor contained in a unit of the neutral gas. The combined error of these defects is additive and probably increases the water-vapor contained in a unit of air by 0.4 to 0.5%. E.J.V.

Advantages of artificial air movement for heat transmission. ANON. *Elektrowärme*, **4** [1], 12–14 (1934).—Several examples are calculated to show how much the heat transmission to the material in a box-type furnace can be improved when the air is artificially circulated. For the same temperature gradient from 4 to 60 times the

amount of heat can be transmitted according to the nature of the material. M.H.

Simplification by combining drying and grinding operations. LINCOLN T. WORK. *Chem. Met. Eng.*, **40** [6], 306–309 (1933).—This combination takes advantage of the principles of drying to produce results rapidly and with little if any impediment to grinding. A high-quality product can be secured due to the intimate contact of the material with air and the close temperature control which may be maintained. Materials which may be dried and ground in one operation with highly satisfactory results include cement raw mixture, limestone, bauxite, kaolin, phosphate rock, barite, and talc. A.K.

Ball milling. A. M. GOW, M. GUGGENHEIM, A. B. CAMPBELL, AND W. H. COGHILL. *Mining & Met.*, **15** [326], 108 (1934).—A method of ball milling using power as an index of mill operation and ascertaining the effects of the set and induced variables is outlined. By recognizing that the amount of ore in the mill is an important inducted variable and depends principally on the size of the discharge trunnion, ball volume, rate of feed, and speed of mill, obstacles formerly met were surmounted. After showing that a 2- x 2-ft. mill differed from commercial mills only in size, the power curves from the small mill were used as a basis of a power formula which was applied with remarkable agreement to two dozen power tests on a variety of commercial mills. A ball size that will ration the grinding to all sizes of the new feed is the first step in stage grinding. By a slight modification of the Rittinger law all grinding results are in terms of useful grinding. E.J.V.

New roll type pyrometer for revolving rolls, cylinders, and driers. ILLINOIS TESTING LABORATORIES, INC. *Fuels & Fur.*, **11** [6], 227 (1933).—A description of this new roll-type pyrometer for measuring surface temperatures of revolving rolls and cylinders or driers is given. E.J.V.

Special drier for clay tile. D. A. MOULTON. *Brick Clay Rec.*, **84** [1], 14–16 (1934).—Several types of driers now in use are described. A double-deck drier was built, the top compartment being the hot-air duct and the lower containing the moving tile, to show that safe drying can be accomplished by means of uniform heat distribution. Full construction and operating details are given. E.J.V.

Basic principles underlying clay drying. H. H. MACEY. Presented at meeting of English Ceramic Society, Stoke-on-Trent, Jan., 1934; *Pottery Gaz.*, **59** [680], 206–207 (1934). E.J.V.

Drying unfired pottery. T. E. SIMPSON. Presented at meeting of English Ceramic Society, Stoke-on-Trent, Jan., 1934; *Pottery Gaz.*, **59** [680], 205–206 (1934). E.J.V.

Researches on drying solid materials. I–II. SABURO KAMEI AND TAMOTSU SEDOHARA. *Jour. Soc. Chem. Ind* [Japan], **36** [12], 645–54*B* (1933).—The process of drying materials under different conditions is discussed. The devices employed are described. M.V.K.

Apparatus for determining ash fusion by the Bunte-Baum method. K. BAUM. *Gas Engr.*, **49** [12], 639 (1932); abstracted in *Fuel Sci. Practice*, **12** [1], 36 (1933). F.G.H.

Lubrication and maintenance of brickmaking machines. O. SKÁLA. *Stavivo*, p. 23 (1933).—Proper lubrication affects power consumption, maintenance costs, and quality of the products. R.B.

Seger cones and defects due to firing. ANON. *Keram. Rund.*, **41** [39], 515–16 (1933).—Defects appearing in Seger cones are discussed. Seger cones are used not only to measure temperature but also to show the effect of the duration of firing, behaving in the same manner as the ware. M.V.K.

Electro-lubrication in ceramics. ANON. *World Power*, **20** [115], 7 (1933).—Electro-lubrication of the cores and liners of hollow ware dies depends on the moisture concentration which takes place at the negative electrode when a direct current of electricity is passed through a plastic mixture of clay and water. The only additions necessary are the anode, a ring of suitable shape mounted back of the die and properly insulated from it, and insulation of the liner from the rest of the machine. Data on commercial installations are given. E.J.V.

Life of high-grade chromium-nickel alloys and their testing. W. HESSENBRUCH AND W. ROHN. *Elektrowärme*, **3** [8], 249–59; [9], 294–97; [10], 317–22 (1933).—Methods of producing Cr-Ni alloys for resisting high temperatures, physical properties of the various alloys, chemical resistance, influence of frequently switching the current on and off, and metallographic investigations are discussed. Almost all Fe containing Cr-Ni alloys when used at high temperatures shows segregation of the compound Fe-Cr-Ni, whereas in the unused state the alloy is a solid solution of Ni-Cr-Fe-Mn-Si; this segregation is greater with a high content of Cr. Illustrated. M.H.

Use of special alloy and heat-treated irons in clay products plants. W. H. MORIARTY. *Brick Clay Rec.*, **84** [1], 30 (1934).—Tests on elevator buckets of malleable iron, Mallix iron, sheet steel, and two specially treated malleable irons showed that Mallix iron had the lowest per cent loss in weight over the same period of operation. It belongs to the low initial cost group of wear-resisting castings. In screen plates it is estimated that Mallix iron plates of the same dimensions as the malleable plates would last about twice as long as the malleable and with 20% more slots and 30% less weight than gray iron plates they would last at least 50% longer. E.J.V.

Standardization of heating elements and autotransformers. K. MERTENS. *Elektrowärme*, **4** [1], 8–9 (1934).—The considerable change in resistance caused by the aging of Silit and Globar heating elements can be economically counteracted by providing autotransformers with definite steps which are selected for a series of standardized elements. A series of elements of Silit and Globar and transformers for operating them are developed. M.H.

Abrasion-resistant castings. WILLIAM C. HARTMANN. *Iron Age*, **132** [3], 20–21 (1933).—H. cites research work to develop a special chrome-molybdenum alloy steel having unusually high resistance to abrasion. This work was stimulated by the relatively short life in the ceramic industries of most of the castings subjected to severe abrasion and in some cases to moderately high impact stresses. The general characteristics of clays, shales, silica glass sand, ganister rock, feldspar, sillimanite, silicon carbide, mullite, and a product designated as aluminium

oxide, to be processed, were studied with reference to the wear on specific parts of the machinery, *e.g.*, muller tires, bottom plates, pug-mill knives, crusher rolls, screen plates, roll shells, and sprockets. The physical properties of the casting developed together with data on performance in a number of ceramic plants are given. A.K.

Resistance to mechanical pressure. Linear deformation and cohesion according to the Jourdain test. VLADIMIR ŠKOLA. *Chim. & ind.* [Special No.], **29** [6], 830–50 (June, 1933).—Jourdain recommends that in the crushing test of structural materials a small rubber disk be placed between the sample and the crushing surface; the results are lower than those obtained by the usual procedure, but it is claimed that there is better concordance between duplicate tests. Comparisons of the two techniques showed that the ratio between the results is not constant but depends on the properties of the material tested. Analysis of the accuracy by the method of least squares showed that both the absolute variation and the relative variation were smaller by Jourdain's technique than by the usual procedure. The experiments were made on a mixture of grog with acid and basic clay, stoneware, and cement testing pieces. M.V.K.

Recent developments in electric bright-annealing furnaces. TAMELE. *Elektrowärme*, **4** [1], 3–8 (1934).—Box-type and continuous furnaces, with and without protective atmosphere for the material, are described, and constructive details are illustrated. Performance curves are given. M.H.

Operation and temperature control of electric furnaces with rectifiers. BUECHLING AND KLEMPERER. *Siemens-Z.*, **13** [10], 300–303 (1933).—Temperature control with grid tube regulators is described. M.H.

Furnaces for high temperatures, especially for ceramic purposes, melting, and forging. H. MASUKOWITZ. *Elektrowärme*, **4** [1], 15–18 (1934).—Construction details and operating data of furnaces which are equipped with a new design of heating element are given. This element is like a ribbon with a reinforcing rib in the middle and permits an almost continuous heating surface to be built before the walls and under the roof; the latter can even be supported by the elements. M.H.

BOOK REVIEW

Functional Size Analysis of Ore Grinds. ARTHUR J. WEINIG. 190 pp., 80 illustrations. *Quart. Colo. School Mines*, Vol. 28, No. 3 (July, 1933).—W. points out that there is no method known at present by which the actual size-weight distribution of grains of any given grind can be determined. Three methods are in use, *viz.*, screen analysis, sedimentation balance analysis, and microscopic grain counting. The screen analysis method, within its physics limits, is generally accepted as the most accurate in determining actual size-weight distribution. W.'s purpose is to set forth a method of evaluating the distribution or frequency of grind products that are too fine to be measured by screens. Thus he begins with mathematical formulas where the actual screening leaves off. Since ore grinds in mill work are initially determined with screens, he uses the constants of screens in developing his mathematical formulas for continuing the weight curve to its fine limit. The advent of flotation has made it necessary to determine with the greatest possible accuracy the fine sizes of a grind. The use of the sedimentation balance and of microscopic grain counting has not produced the required results. The mathematical methods of analysis are designed to reveal the characteristics of ore grinds and to serve as a basis for evaluating the efficiency of ore grinding.

In an appendix W. points out the possibilities of the application of his mathematical form to other fields.

PATENTS

Method and means for testing insulation. E. B. PAINE, J. TYKOCINSKI-TYKOCINER, AND H. A. BROWN (Board of Trustees, Univ. of Illinois). U. S. 1,943,391, Jan. 16, 1934.

Brick machine. E. S. BAER. U. S. 1,943,506, Jan. 16, 1934.

Rotary abrasive blast gun. D. C. COBLE AND C. D. STEINMEIER (American Foundry Equipment Co.). U. S. 1,944,404, Jan. 23, 1934.

Apparatus for preparing ceramic articles. WILLY LENGERSDORFF AND MAX LENGERSDORFF. U. S. 1,944,796, Jan. 23, 1934. Apparatus for continuously manufacturing ceramic articles comprises a work table including roller members forming a continuous path having supporting boards for the molded articles, the path being adapted to convey the articles during the whole process from the molding to the entry into the oven, a heating means below the entire path adapted to heat the articles on the supporting boards during the whole process, lateral guides for the supporting boards on the path, and removable hoods adapted for the continuous control of the articles to be manufactured.

Material sampling system. J. D. BRADFORD AND W. S. MCALEER (Koppers Co. of Delaware). U. S. 1,944,963, Jan. 30, 1934. (1) In combination with a flight conveyer, a sampling gate, a device for operating the gate, electromagnetic control means for the device, a time relay, means for controlling the control, and means connected to and operating in timed relation to the operation of the conveyer for periodically energizing the time relay means and thereby causing the electromagnetic control means to open the gate, maintain the gate open for a predetermined time interval, and then close the gate. (2) In combination with a conveyer comprising a trough and flights in the trough, the trough having a sampling aperture therein, a longitudinally sliding gate for the aperture, means for opening the gate as the front flight of a pair of adjacent flights passes the front edge of the aperture, means for closing the gate as the rear flight reaches the front edge of the gate, and means operatively connected to and operating in timed relation to the movement of the flights for controlling the opening and the closing means for the gate.

Method and apparatus for making ceramic shapes. ELISABETH LUX (Koppers Co. of Delaware). U. S. 1,944,989, Jan. 30, 1934.—A machine for making ceramic shapes comprises a vibrating machine, a mold arranged on the working member of the vibrating machine, a guide arranged vertically above the mold, a slide gliding on the guide, a cover for closing up the interior of the mold and attached to the slide, and means for evacuating the interior of the mold.

Apparatus for testing insulating values. F. C. DOBLE (Doble Engineering Co.). U. S. 1,945,263, Jan. 30, 1934.

Apparatus for pressing clay products. A. E. GUSKEA, STEVE HOMA, AND JOSEPH SCHULTZ. U. S. 1,945,399, Jan. 30, 1934.

Pyrometer and like tubes for protection against furnace gases. TELEGRAPH CONSTRUCTION & MAINTENANCE CO., LTD., WILD-BARFIELD ELECTRIC FURNACES, LTD., AND J. P. D. COLEMAN. Brit. 404,670, Jan. 31, 1934.

Kilns, Furnaces, Fuels, and Combustion

Fundamentals and economies in the clay industries. No. 32. ELLIS LOVEJOY. *Clay-Worker*, **100** [5], 158–61 (1933).—L. describes firing problems under the following heads: (1) relation of setting to firing, (2) conditions at the base of the kiln, and (3) firing curves. For No. 31 see *Ceram. Abs.*, **13** [2], 46 (1934); for No. 33 see this issue, p. 89. A.J.M.

Slagging of fuel-oil ash. L. R. FAULKNER. *Bull. Amer. Ceram. Soc.*, **13** [2], 45–46 (1934).

New electric kiln. ROYCE & BROWN. *Pottery Gaz.*, **59** [680], 203 (1934).—In an entirely new type electric kiln, a stained glass kiln with a separate annealing chamber and a pottery kiln with a separate enclosed chamber for preheating the ware are described. The elements are contained in detachable units, "tops," "sides," "bottoms," etc. Illustrated. E.J.V.

Glost kilns. E. WIEDEMANN. *Glashütte*, **63** [28], 467–69 (1933).—After discussing the requirements of a modern kiln, W. describes an electrically or gas-heated tunnel kiln of the Surface Combustion Co. General characteristics of German tunnel kilns are given. The kilns have preheating, firing, and cooling zones. The muffles are made of silicon carbide plates. Coke, lignite, coal, oil, and gas are used as fuel, the latter being especially advantageous. M.V.K.

How to repair internal kiln walls. ANON. *Brit. Clayworker*, **42** [500], 268 (1933).—When the internal walls of continuous kilns bulge through the breakage of the headers bonding the internal linings to the bodies of the walls the best way to make repairs is to slope the new internal courses in two directions, the upper brick upward into the wall and the lower ones downward. Although the wall face will not be smooth, relining the kiln will be unnecessary for a much longer period than if the brick are placed in the kiln wall horizontally. R.A.H.

Kieselguhr and insulation in the ceramic industry. LUCIEN AUGÉ. *Céramique*, **33** [546], 217–20 (1933).—Kieselguhr is a siliceous substance made up of microscopic shells called "diatoms." It has low heat conductivity, good strength, and a fusion point of about 1300°C. It saves a great deal of heat, particularly on continuous tunnel kilns. M.H.B.

Recent developments in design and operation of industrial furnaces. G. A. MERKT. *Fuels & Fur.*, **11** [6], 225 (1933).—After reviewing the essential features which have entered into the construction of fuel-fired furnaces up to the present, M. considers the combustion process and its relation to furnace work in the light of more recent understanding. The importance of the "thermal balance" of the furnace is pointed out. E.J.V.

Babcock & Wilcox circular multifuel burner. ANON. *Power Plant Eng.*, **37** [8], 363 (1933).—Liquid, gaseous, or solid fuels in pulverized form may be injected into the furnace through a common circular throat opening, either one at a time or in combination. An adjustable deflector, mounted at the furnace end of the primary-air and pulverized-coal pipe, insures intimate mixing with the secondary air and furnishes a high degree of turbulence. Illustrated. E.J.V.

Use of special atmospheres for industrial furnaces. W. WIRT YOUNG. *Gas Age-Rec.*, **73** [3], 56–58 (1934).—The recently developed diffusion flame burner produces a new variation of atmospheres from a direct flame. Another variation of using direct burning gas for atmosphere is the commonly known gas curtain on an electric furnace. The use of hydrogen, steam, electrolene, methanol, dissociated ammonia, hydrocarbons, products of combustion, and treated city gas for producing special atmospheres is discussed. Study of their use and the application of special atmospheres to furnaces is urged. Illustrated. E.J.V.

Principles of construction of low pressure burners. H. FLASDIECK. *Feuerungstechnik*, **21** [1], 10 (1933); abstracted in *Fuel Sci. Practice*, **12** [2], 72 (1933). F.G.H.

New method of calculating the calorific value of a fuel from its ultimate analysis. E. S. GRUMELL AND I. A. DAVIES. *Fuel Sci. Practice*, **12** [6], 199–203 (1933).—The Vondracek formula is shown to give better average agreement with the determined calorific value than the Dulong formula within the range of 78 to 93% carbon. It is not as accurate as the Dulong formula within 78 to 85 or 86% carbon where the average error is practically zero. Above this limit the Dulong formula rapidly increases the average error until it is finally $> +120$ cal., whereas in no case does the Vondracek formula show an average difference $> +72$ cal. The development of a modified formula is presented which gives satisfactory results over the whole range. F.G.H.

Calorific value of pure coal substance. A. PURDON AND S. SAPGIRS. *Fuel Sci. Practice*, **12** [2], 40–46 (1933).—Three hypotheses are considered in searching for an explanation for the variation of the calorific value of pure coal substance in coals of the same origin, but having different quantities of ash. Variations of the calorific value increase with increasing ash content. Data on many coals are given in conjunction with each hypothesis. The authors conclude that the observed decrease in the calorific value of the pure coal substance corresponding with increasing quantities of ash is mainly due to the difference between mineral matter and ash. In coals having up to 5% ash the error is small. In coals having larger quantities of ash, the determination of the mineral matter is indispensable to the correct calculation of the calorific value of the pure coal substance. Illustrated. F.G.H.

Mechanism of the alkaline permanganate oxidation of

coal. W. FRANCIS. *Fuel Sci. Practice*, **12** [4], 128–38 (1933).—The use of alkaline permanganate solution as a reagent in investigating the constitution of various coals is described. The nature of its attack upon coal is studied. Results are given of a series of quantitative oxidations by alkaline permanganate under carefully controlled conditions from which conclusions have been drawn regarding (1) the influence of particle size on the reaction, (2) the nature of the principal chemical reaction taking place (with special reference to the relationship between velocity of reaction and rank of coal), and (3) the influence of different chemical constituents on the oxidation-time curve. Illustrated. F.G.H.

Reactivity of coal: The "permanganate number." F. HEATHCOAT. *Fuel Sci. Practice*, **12** [1], 4–9 (1933).—A quick and accurate method is described for gaging the rank of a coal by measuring the reactivity of the ulmins toward alkaline permanganate under regulated conditions. The result is expressed as a "permanganate number." Illustrated with curves. F.G.H.

Pressure and volume of gas contained in coal. H. BRIGGS. *Colliery Eng.*, 9 [12], 416 (1932); abstracted in *Fuel Sci. Practice*, **12** [1], 36 (1933). F.G.H.

Microscopical examination of coal. J. LOMAX. *Colliery Guard.*, **145**, 1031 (1932); abstracted in *Fuel Sci. Practice*, **12** [1], 36 (1933). F.G.H.

Softening of coal on heating. H. A. PIETERS. *Gas*, **52**, 478–82 (1932); abstracted in *Fuel Sci. Practice*, **12** [7], 252 (1933).—A new method for the microscopic study of the softening and carbonization stages of coal is described with photomicrographs. F.G.H.

Changes in the constitution and the caking power of coal during heating to the plastic state. K. BUNTE, H. BRUCKNER, AND H. G. SIMPSON. *Fuel Sci. Practice*, **12** [7], 222–32 (1933). F.G.H.

Caking phenomena of coals and method of testing. T. SHIMMURA AND H. NOMURA. *Fuel Sci. Practice*, **12** [6], 194–95 (1933). F.G.H.

Caking constituents and the coking properties of coal. T. SHIMMURA. *Fuel Sci. Practice*, **12** [6], 204–209 (1933).—Illustrated. F.G.H.

Evaluation and blending of coals for coke making. R. A. MOTT. *Fuel Sci. Practice*, **12** [1], 13–25 (1933).—The evaluation and the testing of coals for the manufacture of coke are described and illustrated. F.G.H.

Contribution to the problem of the caking and swelling of bituminous coal. H. BROCHE AND H. SCHMITZ. *Fuel Sci. Practice*, **12** [2], 47–51 (1933). F.G.H.

Application of ash-correction formulas to Alabama coals. E. S. HERTZOG. *Fuel Sci. Practice*, **12** [4], 112–18 (1933). F.G.H.

Behavior of coal sulfur on burning. J. GYORKI. *Brennstoff-Chem.*, **14**, 85 (1933); abstracted in *Fuel Sci. Practice*, **12** [4], 144 (1933). F.G.H.

Behavior of finely ground coals when subjected to extraction and low-temperature carbonization. F. FISCHER, K. PETERS, AND W. CREMER. *Fuel Sci. Practice*, **12** [5], 148–55 (1933). F.G.H.

Modern methods of low-temperature carbonization and the preparation of artificial anthracite. C. BERTHELOT. *Chim. & ind.*, **29** [1], 18 (1933); abstracted in *Fuel Sci. Practice*, **12** [2], 72 (1933). F.G.H.

Experimental determination of the flame temperature of complex mixtures of combustible gases and a method for calculating them. B. LEWIS, H. SEAMAN, AND G. W. JONES. *Jour. Frank. Inst.*, **215** [2], 149–67 (1933); abstracted in *Fuel Sci. Practice*, **12** [3], 108 (1933).—Data are given showing how the flame temperatures of hydrogen, methane, and carbon monoxide are affected by the addition of various amounts of nitrogen and carbon dioxide. The flame temperatures of complex mixtures of combustible and industrial gases were also determined. A method is described for calculating the maximum flame temperature of any mixed gas. Good agreement was found between the calculated and the determined temperatures of the gases used for the experiments. F.G.H.

Desirable gas character in the finish fire in firing sewer pipe. FRIEDRICH DETTMER. *Ber. deut. keram. Ges.*, **14** [10], 438–45 (1933).—Stoneware bodies are fired between 1150 and 1300°, usually between 1250 and 1300°. The temperature differences in commercial kilns cause the generally weak finishing fire in spots in the kiln, and the beginning of the dissociation range of iron oxide arriving at the same time results in porous bodies with an oxidizing fire. The decomposition of the sulfate formed during the preliminary heating occurs during the period of incipient softening in an oxidizing fire and delays the vitrifying fire; this is another cause for porous material. At this temperature the remaining parts are still porous. In an oxidizing atmosphere salt is not serviceable for the production of a strong cohesive glaze. It is necessary, therefore, to use a reducing finish fire for stoneware firing, as long as an extremely low firing body is not used. Only the lower fired bodies can be fired in an oxidizing atmosphere without risk when the salt is applied in a reducing atmosphere. The reduction in the finish fire is not to be carried so far that carbides or carbon deposits form, as the strength of stoneware body is lessened thereby and the porosity is increased. The carbon present in the clay in the body should be burned out by a proper firing prior to the inception of the finish firing. It is shown by commercial tests that the best quality is obtained in bodies of dark stoneware, fired under reducing conditions, with no carbon deposits present. E.J.V.

Combustion chart solves fuel problems for gasoline, coal, and natural gas. I–II. E. THERKELSEN. *Power*, **77** [11], 600–601; [12], 652–53 (1933).—A standard computation form, based on the molal method of computation, is presented for the rapid and accurate solution of combustion problems involving solid, liquid, or gaseous fuels. A single form, which will serve for any fuel, may easily be duplicated as mimeographed, zincographed, or blueprinted sheets of $8^1/_2$- x 11-in. notebook size. Illustrated. F.G.H.

Combustion of carbon. R. WIGGINTON. *Fuel Sci. Practice*, **12** [4], 118–28 (1933).—The development of a standardized method of measuring the rates of combustion of different varieties of carbon is described and illustrated. F.G.H.

Quantitative estimation of sulfur and halogens in combustible substances. W. GROTE AND H. KREKELER. *Z. angew. Chem.*, **46**, 106 (1933); abstracted in *Fuel Sci. Practice*, **12** [3], 108 (1933). F.G.H.

Derivation and use of common formulas used in com-

bustion calculations. P. B. PLACE. *Combustion*, **4** [12], 27 (1932); abstracted in *Fuel Sci. Practice*, **12** [1], 36 (1933). F.G.H.

Powdered fuel firing equipment. P. HOWDEN. *Power Engr.*, **28** [1], 17 (1933); abstracted in *Fuel Sci. Practice*, **12** [2], 72 (1933). F.G.H.

Modern mechanical stoking. RUETZ AND CO. *Slavivo*, p. 53 (1933).—Fifteen hundred brick plants use about 50,000 stokers of the type described. R.B.

BOOK AND REPORTS

Steam and Gas Engineering. T. E. BUTTERFIELD, B. M. JENNINGS, AND A. W. LUCE. D. Van Nostrand Company, Inc., New York, 1933. 2nd ed. 488 pp. Price $4.50. Reviewed in *Power*, **77** [12], 657 (1933).—Chapters on combustion and the firing of pulverized coal, gas, and liquid fuels are included in this volume. F.G.H.

Burning of liquid and gaseous fuels. ANON. *Edison Elec. Inst. Comm. Rept.*, No. A4; *Power*, **77** [11], 597 (1933).—Data on the following subjects are included in this report: (1) rates of furnace heat liberation, (2) gas metering, (3) comparison of solid-fuel furnaces after conversion to oil or gas, (4) comparison of gas and oil-fired furnace operation, (5) deterioration of fuel oil in storage, and (6) automatic combustion control. F.G.H.

Pulverized fuel. ANON. *Edison Elec. Inst. Comm. Rept.*, No. A6; abstracted in *Power*, **77** [11], 597 (1933). F.G.H.

Stoker equipment and furnaces. ANON. *Edison Elec. Inst. Comm. Rept.*, No. A7; abstracted in *Power*, **77** [11], 597 (1933). F.G.H.

Low-temperature carbonization: Narrow brick retorts at the Fuel Research Station. J. F. SHAW. *Fuel Research Tech. Paper*, No. 35. H. M. Stationery Office, London, 1933. Price 6d. *Fuel Sci. Practice*, **12** [3], 108 (1933). F.G.H.

PATENTS

Tunnel kiln. HARROP CERAMIC SERVICE CO. Brit. 404,328, Jan. 24, 1934.

Tunnel kiln and process for operating it. GIBBONS BROS., LTD. (C. Dressler). Brit. 405,143, Feb. 7, 1934.

Geology

Studies on zeolites. IV. Ashcroftine (kalithomsonite of S. G. Gordon). MAX H. HEY AND F. A. BANNISTER. *Mineralog. Mag.*, **23** [140], 305–308 (1933).—"Ashcroftine" is a name proposed to replace the name "kalithomsonite" formerly used for this mineral. The name kalithomsonite is retained properly for the artificial potassiferous thomsonites prepared by one of the authors. Ashcroftine is a tetragonal mineral with a unit cell measuring c 17.49, a 34.04Å and containing approximately $40[NaK(Ca,Mg,Mn)Al_4Si_8O_{16}\cdot 8H_2O]$. Its refractive indices are ϵ 1.545, ω 1.536, and it occurs as small needles bounded by the cleavage forms $a(100)$, $c(001)$. Its specific gravity is 2.61 ± 0.05. **V. Mesolite.** *Ibid.*, **23** [143], 421–47 (1933).—Mesolite is an independent species, isostructural but not isomorphous with natrolite and scolecite. Five new analyses have been made. The unit cell, of dimensions a 56.7, b 6.56, c 18.44Å, β 90°0′, contains $Na_{16}Ca_{16}Al_{48}Si_{72}O_{240}\cdot 64H_2O$. The space-group is C_2^3, but there is a marked approximation to the orthorhombic space-group C_{2v}^{19}. Goniometric measurements are in excellent agreement with the X-ray data and show a marked development of vicinal pyramids. The optical properties, vapor pressure, and base exchange of mesolite have been studied in considerable detail. It has been found that a distinction may be made between mesolite and natrolite by X-ray methods, and that, by the action of fusions of potassium thiocyanate, lithium nitrate, and silver nitrate on mesolite, compounds identical with similar derivatives prepared from natrolite may be obtained; these have the natrolite structure. The vapor-pressure measurements have been checked by a direct determination of the heat of hydration of partially dehydrated mesolite. Mesolite has been observed on specimens from eight localities new for the species. For Part III see *Ceram. Abs.*, **12** [9], 340 (1933). A.K.

Clay minerals and bauxitic minerals. A review and classification based on a statistical method. S. I. TOMKEIEFF. *Mineralog. Mag.*, **23** [143], 463–81 (1933).—A statistical study of clay and bauxitic minerals consists in plotting all available analyses of these minerals on two triangular diagrams and constructing frequency curves for the cardinal ratios and leads to a classification on a purely chemical basis. It is suggested that among substances claimed to be minerals only a few belong to definite mineral species, and the others are probably mixtures of these selected minerals or their hydration products or colloidal hydrates of variable composition. The distinct crystalline mineral species selected are pyrophyllite ($H_2O\cdot Al_2O_3\cdot 4SiO_2$), kaolinite and its isomers ($2H_2O\cdot Al_2O_3\cdot 2SiO_2$), diaspore and its isomers ($H_2O\cdot Al_2O_3$), and gibbsite and its isomers ($3H_2O\cdot Al_2O_3$). Other substances, such as termierite, anauxite, allophane, etc., are suggested as probable species, without any clear statistical evidence. The bentonitic minerals, not belonging strictly to the pure hydrous aluminum silicates, are placed in a separate group. A.K.

New barium plagioclase feldspar. S. R. NOCKOLDS AND E. G. ZIES. *Mineralog. Mag.*, **23** [143], 448–57 (1933).—The plagioclase feldspar described appears to be unique. Ginzberg, according to Eskola, found that the triclinic anorthite could take up limited amounts of barium feldspar in solid solution, whereby the optic axial angle diminishes. This is also true with the natural plagioclase since the barium plagioclase has a lower axial angle than that of the normal plagioclase (between 70% and 80% An) to which it most closely corresponds with respect to position of its optic plane, optic axes, etc., and to the positions of the poles of its twin-planes and axes for the various types of twinning found. A.K.

Portlandite, a new mineral from Scawt Hill, Co. Antrim.

C. E. TILLEY. *Mineralog. Mag.*, **23** [142], 419–20 (1933). The name Portlandite is proposed for the occurrence of $Ca(OH)_2$ as a well-defined species in the contact zone of Scawt Hill. It occurs as a common product of the hydration of Portland cement, and crystals from this source have provided the first reliable physical and optical data on crystalline $Ca(OH)_2$. A.K.

Biographical notices of mineralogists recently deceased. V. L. J. SPENCER. *Mineralog. Mag.*, **23** [141], 337–63 (1933).—A list of forty-one short biographical sketches of world-renowned mineralogists is given. A.K.

Studies of refractory materials. XV. Feldspar. ANON. *Refrac. Jour.*, **10** [1], 26 (1934).—The occurrence and properties of feldspar are described. For Parts XIII and XIV see *Ceram. Abs.*, **13** [3], 63 (1934). A.J.M.

Artificial transformation of feldspar into kaolin. ROBERT SCHWARZ AND GEORG TRAGESER. *Z. anorg. allgem. Chem.*, **215** [2], 190–200 (1933).—The authors attempted to follow the weathering processes which cause the transformation of feldspars into aluminium hydrosilicates, clay, and kaolin. The behavior of feldspars to all aqueous and gas-forming agents which may be of importance in the weathering processes was followed at various temperatures and pressures. Hydrochloric vapors were included in the study. Some conditions under which kaolin forms from feldspar were determined. The reactions were followed by chemical analysis and by X-rays. L.T.B.

Preliminary results of researches on Danish ceramic clays. ELLEN LOUISE MERTZ. *Lerindustrien*, No. 10, pp. 55–57; No. 11, pp. 61–63; No. 12, pp. 67–70 (1933); abstracted in *Keram. Rund.*, **41** [34], 451 (1933).—Investigations on the melting point, firing color, structure at different temperatures, shrinkage due to drying and firing, degree of water absorption, and tendency to effloresce are discussed. The results are tabulated. M.V.K.

Eruptive rocks as raw materials for the ceramic and glass industries. EDMUND MOTSCHMANN. *Steinindustrie*, **27** [5–6], 30–32 (1932); abstracted in *Glastech. Ber.*, **11** [5], 184 (1933).—Deposits and composition of the chief German eruptive rocks and their use in the ceramic and glass industries are discussed. M.V.K.

Chemistry of kaolin. LUDWIG WOLF. *Ber. deut. keram. Ges.*, **14** [9], 393–403 (1933).—Properties of comparatively pure clays are enumerated. Pure clays and kaolins consist essentially of clay substance and are practically free of any organic constituents. Clays and kaolins with a fixed content of organic constituents show different behavior than pure materials. Reactions which have not been understood hitherto are now proved attributable to the organic constituents. Little is known of the influence of the organic constituents on the washing process, liquefaction, aging, drying, and firing. More work is necessary to clear up the existing questions. E.J.V.

Clay dikes in Redstone coal, West Virginia and Pennsylvania. PAUL H. PRICE. *Bull. Amer. Assn. Petroleum Geol.*, **17** [12], 1527–33 (1933).—These dikes are so common that they are believed to result from a definite set of conditions. Similar conditions associated with another coal should produce clay dikes. A stratum of plastic clay directly below or above the coal is necessary. A well-compacted coal, when stressed tangentially, develops a joint system with one set normal to and another set parallel to the direction of stress. The same coal, when stressed normal to the bedding, acts as a brittle material and forms sets of compressive shear fractures, inclined at an angle to the bedding averaging 40 to 50°. Fractures passing through the coal penetrate the underclay or an overlying clay to form a line of weakness for the clay to flow through, equalizing differential pressures and forming clay dikes. G.M.H.

BOOKS AND BULLETINS

On the Mineralogy of Sedimentary Rocks. P. G. H. BOSWELL. Thos. Murby & Co., London, 1933. x + 393 pp. 21s and duty. Reviewed in *Econ. Geol.*, **28** [8], 789 (1933).—An account of the progress made in the study of sedimentary rocks through the aid of heavy minerals is given. J.L.G.

Mineral Deposits of the Canadian Shield. E. L. BRUCE. Macmillan Co. of Canada, Toronto, 1933. xxiv + 428 pp., 161 figs. Reviewed in *Econ. Geol.*, **28** [8], 790 (1933).—A general and rather elementary treatment of the principles of geology and ore deposition occupies the first 105 pages. The rest of the book describes the geology, both local and in its regional relationship, of several dozen selected mines. It is well organized and presented. Excellently illustrated. Bibliography. J.L.G.

History of the Theory of Ore Deposits with a Chapter on the Rise of Petrology. THOMAS CROOK. Thomas Murby & Co., London, 1933. 163 pp. 10s 6d. Reviewed in *Econ. Geol.*, **28** [8], 787–88 (1933).—A readable account of the history of the development of various theories used to explain the origin of ore deposits is presented. J.L.G.

Geology of Texas. E. H. SELLARDS, W. S. ADKINS, AND F. B. PLUMMER. *Univ. of Texas Bull.*, No. 3232, 1007 pp. (1933). 9 plates, 42 figs., map in colors. Bur. of Economic Geol., Austin, Texas. Paper $3.25, cloth $4.00. Reviewed in *Bull. Amer. Assn. Petroleum Geol.*, **17** [11], 1398 (1933). G.M.H.

Geology of Lafayette and St. Martin Parishes. HENRY V. HOWE AND CYRIL K. MORESI. *Louisiana Dept. of Conservation Geol. Bull.* [New Orleans], No. 3 (1933); reviewed in *Bull. Amer. Assn. Petroleum Geol.*, **17** [11], 1398 (1933).—Bibliography and illustrations. G.M.H.

Historical Geology. RAYMOND C. MOORE. McGraw-Hill Book Co., Inc., New York, 1933. 649 pp., 400 illustrations. Price, cloth, $4.00 net. Reviewed in *Bull. Amer. Assn. Petroleum Geol.*, **17** [11], 1394–95 (1933). G.M.H.

Abstracts of current articles on geophysical prospecting. F. W. LEE. *Bur. Mines Periodical Service Rept.*, GA55, 28 pp., 10¢. See also *Ceram. Abs.*, **13** [2], 47 (1934). R.A.H.

Talc and ground soapstone. ALDEN H. EMERY AND B. H. STODDARD. *Bur. Mines Mineral Rept.*, 1932–1933. Separate chapter, 7 pp., 5¢. R.A.H.

Chemistry and Physics

Nature of ceramic clays. K. ENDELL, U. HOFMANN, AND D. WILM. *Ber. deut. keram. Ges.*, **14** [10], 407–38 (1933).—All ceramic clays (kaolins, ball clays, and fire clays) consist (apart from mechanical admixtures of quartz, feldspar, mica, etc.) of homogeneous crystalline material whose crystal lattice is the same as that of kaolinite. Kaolinite lattices are also obtained for washed products of ceramic clays which are considered as 0.5μ. The kaolinite lattice remains constant for a thoroughly powdered crystal. Kaolinite does not seem to decompose through hydrolysis. Ball clays and fire clays (*i.e.*, clays with total absorption capacities, T-values of 7 to 15 milliequivalents of absorbed cations per 100 g. dry substance) exhibit a clearly marked internal interference (001) instead of the kaolinite interference. Probably the question relates to great admixtures (+5%), which have a micaceous structure. The internal cause of the total absorption capacity of clays for cations is that their T-values can lie in the fineness of the lattice arrangement, which from photometric X-ray pictures of ceramic clays appears to result from the relation of T-values to the lattice arrangement corresponding to Laue's *n*-value. Besides kaolinite there is another clay mineral, montmorillonite. The crystal structure of montmorillonite, found in bentonite and in many soils, is described for the first time. All previous investigators found an interference 001 near the punching-through point, which fixed an interval between level planes. By determining the specific gravity and the true chemical composition by removal of the excess water it was possible to advance a crystal structure model of montmorillonite. Accordingly there is one aluminum hydroxide plane chemically bound between two Si-O-Si planes. The "free space" between two level planes in montmorillonite is $2^1/_2$ times as great as in kaolinite. From this structure, a unidimensional swelling of the lattice of montmorillonite by water in the direction of the *c*-axis can be detected. This swelling behavior of montmorillonite, which does not occur in pyrophyllite and the 001-interference of ball clays, indicates that the lattice is sensitive to water and can be easily destroyed by hydrolysis. It may also be the reason for the great drying shrinkage, plasticity, dry strength, and flowability of bentonite. The conception of clays as colloid electrolytes arising from the Pauli-Valkos electrochemical theory of colloids (first applied to ceramic clays by P. Vageler in 1932) was proved serviceable for practice by reëxamination of about 100 ceramic clays and bentonites from three different localities. The two clay minerals, kaolinite and montmorillonite, are distinguishable by a more or less strongly developed dissociated crystal surface. All technically important properties of ceramic clays in the raw state, such as drying shrinkage, plasticity, dry strength, etc., are a function of the water-combining power of the cations adsorbed on the crystal surfaces of the clay particles. The quality of clay is dependent therefore on the amount of the adsorbed cations (T-value) and on the individual compositions of the T-values. If the chemical structure of the crystal lattice is changed by the transition from the ceramic clays with kaolinite lattice to bentonites with montmorillonite lattice an additional change of all ceramic properties occurs. A change in the individual complex coating of kaolins and bentonites will influence the plasticity, drying shrinkage, resistance to breakage, and flowability. Only in the plasticity can a deterioration be detected with constant T-value. An optimum is exhibited in the naturally produced complex coating of ceramic clays which can therefore probably be made plastic only by the addition of materials with higher T-values. Clays are hydrated aluminum silicates, which, according to investigations to date, crystallize in the crystal lattice of kaolinite or montmorillonite. They have such a small crystal size that the amount of dissociable base bound on the crystal surface does not attain a measurable amount. The X-ray optical and colloidal chemical investigations of clays, besides the older chemical and ceramic tests, facilitate the exact knowledge of foreign and the discovery of equivalent domestic clay materials. In many cases it was possible, by the importation of foreign clays such as ball clays, to effect advantageous economies. Illustrated. E.J.V.

Dehydration heat of clays. H. ELSNER. *Ceram. Ind.*, **22** [2], 93 (1934).—In the energy balance of ceramic furnaces, the heat expended for dehydrating clay at 500°C plays an important rôle. An incorrect value for actual practice, 135 gram calories per gram of kaolin, has been used for the dehydration in energy balances up to this time. If the different specific heats of kaolin and metakaolin are kept in mind and consideration is given to the energy content of the water expelled from the kaolin at 500°C, a value of 213 ± 8 cal. for the dehydration heat at 450°C is obtained. In actual practice it is recommended that the value of 230 cal. be used, since dewatering is done at higher temperatures which approach 550°C. Another reason is that the water is held more tenaciously in natural products than in the dehydrated and resoaked batches common in ceramic practice. E.J.V.

Base-exchange equilibria in clays. C. E. MARSHALL AND R. S. GUPTA. *Jour. Soc. Chem. Ind.* [London], **52** [51], 433–43*T* (1933).—When a sufficiently wide range of concentrations is chosen none of the base-exchange equations so far proposed is satisfactory. The clays studied were well-defined mineralogically and accurate analytical data are presented for the following reactions: Na-clay + KCl, Na-clay + $CaCl_2$, Na-clay + $AgNO_3$, H-clay + $AgNO_3$, H-clay + Tl_2SO_4. In the Na-clay + $AgNO_3$ and H-clay + $AgNO_3$ systems electrometric measurements of silver-ion activities were made and the dissociation of silver clays in the absence of electrolyte was also studied electrometrically. Bentonite (montmorillonite) has too high a dissociation to be classed as a weak electrolyte. In the H-clay + Tl_2SO_4 systems electrometric measurements of both H^+ and Tl^+ were made. It was concluded that the substitution of activities for concentrations in the simple mass-action equations does not suffice to make them valid. The peculiarities of the dissociation of the clays are shown to be important and fundamental. A.J.M.

Adsorption systems of kaolin and clays with liquids in connection with the phenomenon of plasticity. ERHARD GRUNER. *Z. anorg. allgem. Chem.*, **215** [1], 1–18 (1933).—Vapor-pressure curves of systems of clays and kaolins with water, ammonia, alcohols, CS_2, SO_2, CCl_4, and C_6H_6

were determined by the dynamic method. Vapor-pressure curves of nonplastic systems of clays are horizontal (pressure remains practically constant) until almost all of the liquid phase is evaporated; the vapor pressure then diminishes rapidly. Vapor-pressure curves of plastic systems of clays show a strong adsorption of the dispersion medium. The more plastic the system, the more gradual is the decrease in pressure which may be used to measure the plasticity. Only those liquids which are examples of an asymmetric dipole form plastic masses with clays. The dehydration of clays and kaolin by liquid ammonia was studied. L.T.B.

Considerations on the classical processes of complete analysis of earths and refractory materials, feldspar, kaolin, and glass. A. NOEL. *Rev. belge ind. verrières, céram., émail.*, **4** [12], 266–68 (1933).—After a brief review of methods used for analyzing silicates and other materials, N. describes the sulfo-hydrofluoric method of attack on various silicates (glass, refractories, etc.). Two samples of the material, 1.2 g. each, are calcined. The residues are treated with 3 cc. H_2SO_4 (25%) and 15 cc. HFl and evaporated; some HFl is added and the whole is evaporated to eliminate HFl. The residues are heated until they are liberated from the free H_2SO_4. After this, they are calcined in a muffle (900°), cooled, and weighed. The first sample is then treated with 5 cc. HCl and 10 cc. water, heated, and decanted into a 500-cc. "Berlin vessel." It is diluted with 250 cc. boiling water. Because of the high temperature of calcination, the greater part of the alumina remains insoluble, while iron is dissolved completely. The dissolved parts of these oxides are recuperated by precipitation with excess ammoniac after oxidation with perhydrol; the sample is boiled, filtered, washed with boiling water and 1 drop ammoniac, and calcined at a high temperature. The precipitate obtained contains Fe_2O_3, Al_2O_3, and TiO_2. The filtrate is acidified with HCl heated to boiling, and treated with barium chloride which precipitates SO_3. The barium sulfate obtained is weighed, permitting the calculation of the corresponding sulfuric anhydride. The sulfuric anhydride added to the loss of weight resulting from the sulfo-hydrofluoric attack corresponds to the silica of the product examined. The precipitate of the oxides is weighed and treated with SO_4KH in a muffle and then treated with 200 cc. water and 10 cc. H_2SO_4. The solution is reduced by metallic zinc (*pro analyzi*). After the completion of the reduction of the iron, it is treated with potassium permanganate. The difference in weight yields the alumina and titanium. The second sample, treated in the kiln under the same conditions, is treated with 15 cc. water, heated, and decanted into an Erlenmeyer flask; 3 cc. Na_2CO_3 and several drops of perhydrol are added and the whole is boiled. It is filtered and the precipitate washed; it contains alumina, iron, lime, and magnesia in the form of carbonates. The filtrate is treated with 10 cc. HCl and heated to boiling; it is precipitated with surplus ammoniac using red methyl as indicator. After one-half hour, it is filtered and washed, 1 cc. H_2SO_4 is added, and it is evaporated to 50 cc. and decanted to determine alkalis. In the case of glass the determination is made immediately. For an exact analysis of materials rich in alkalis, potassium is precipitated with platinum chloride. M.V.K.

Melting process of soda-alkaline earth glasses. OSCAR KNAPP. *Keram. Rund.*, **41** [36], 471–73 (1933).—According to the evidence of analytical results and photos, the formation of glass proceeds in the following way: The formation of silicates starts at 800°, with the formation of little barium silicates which cover the surface of the sand grains in a thin layer. With increased temperature (900°), the silicates of lime, magnesia, and soda originate; they form opaque salts covering the sand grains. With a further increase in temperature, the silicates start melting and the sand grains become translucent and then transparent. At 1100° some of the silicates become glassy. The assumption that the dissolving tendency of silica is more important than the diffusion of basic ingredients during melting was not confirmed. Silicates originate first through the diffusion of bases into the sand grains (even in solid state) and only after melting of these salts at higher temperatures does the dissolving tendency of silica appear. The results confirm the assumption that the silica remains in the interior of the sand grains while their surface changes into silicates. The theory that the formation of alkali silicates (which originate through the formation of foam or the penetration into the haloid membrane of sand grains) precedes the formation of other silicates could not be confirmed. The bases present enter into reaction almost simultaneously. It was found that during the formation of glass the basic ingredients react with the silica while yet in solid state; the solid silicates form an opaque layer on the surface of sand grains. With increased temperature the silicates melt, diffuse into the interior of the sand grains, and form a solution with the free silica still present. M.V.K.

Rate of crystallization of undercooled melts. W. REIDERS. *Rec. trav. chim.*, **51**, 589 (1932); abstracted in *Glastech. Ber.*, **11** [6], 212 (1933).—The true dependence of the rate of crystallization on the temperature is discussed, and a formula is developed from which the course of the curve of the rate of crystallization is indicated. The change of the rate of melting with temperature and the rate of conversion in solid state is discussed. M.V.K.

Determining viscosity of melts in the 2-component system $NaPO_3$–$NaBO_2$. M. VOLAROVICH AND D. TOLSTOI. *Compt. rend. acad. sci.* [U.S.S.R.], p. 269 (1932); abstracted in *Sprechsaal*, **66** [48], 823 (1933).—Viscosity temperature curves of B_2O_3, $NaPO_3$, $NaBO_2$, and of mixtures with 20% $NaBO_2$, 38% $NaBO_2$, and 60% $NaBO_2$ are given. Differences of the temperature limits of undercooling show that only one isotherm viscosity combination curve (at 650°) can be indicated. A comparison with the melting curve does not permit any conclusion as to the presence of chemical compounds. The mixture with 60% $NaBO_2$ showed abnormal viscosity. The viscosity of $NaPO_3$ and of $NaBO_2$ was very low, below the melting point. The results are tabulated. M.V.K.

System $2FeO{:}SiO_2$–FeS. B. P. SELIVANOV, A. S. GINZBERG, AND S. I. NIKOLSKI. *Sov. Vs. Inst. Met.*, No. 3–4, pp. 74–78 (1931); abstracted in *Sprechsaal*, **66** [48], 823 (1933).—The melting diagram showed a solid solution of FeS in $2FeO{\cdot}SiO_2$ and inversely a separation into component parts appears in the melting region. The eutectic is about 940° and has a composition of 43% $FeO{\cdot}SiO_2$ and 57% FeS. M.V.K.

System SiO_2–Al_2O_3–TiO_2. VLADIMIR ŠKOLA. *Chim. & ind.* [Special No.], **29** [6], 822–24 (June, 1933).—In evaluating Al silicates the current practice of considering TiO_2 as equivalent to alumina is inaccurate. TiO_2 does not improve the refractory quality and generally lowers it. The equilibria of the system SiO_2–Al_2O_3–TiO_2 should be thoroughly investigated to deduce the proper method of expressing Al_2O_3 for commercial purposes. M.V.K.

Culture of certain silicate gardens. J. G. VAIL. *Chem. & Ind.*, **53** [1], 3–10 (1934).—V. describes colloidal silicate solutions giving the variations of specific gravity, viscosity, solids, and p_H with the $Na_2O : SiO_2$ ratio. The crystalline soluble silicates are briefly described. The uses of the soluble silicates are outlined and a short bibliography is appended. A.J.M.

Determination of graphitic silicon in a siliceous residue. L. H. CALLENDAR. *Analyst*, **58**, 580–94 (1933).—The gasometric method is adopted for measuring H evolved according to the equation $Si + 2NaOH + H_2O = Na_2SiO_3 + 2H_2$, hence 0.1 mg. Si = 0.16 cc. H at N.T.P. H.H.S.

Spot test for detection of free basic oxides in glass. F. FEIGL. *Mikrochemie*, **13**, 139–40 (1933); *Analyst*, **58**, 642–43 (1933).—A mixture of $MnSO_4$ and Ag_2SO_4 develops a gray color in the presence of free basic oxides. H.H.S.

Determination of cadmium in presence of zinc. A. PASS AND A. M. WARD. *Analyst*, **58**, 667–72 (1933).—Beta-naphthoquinoline in the presence of KI precipitates Cd as $(C_{13}H_9N)_2\ H_2CdI_4$. Interfering metals (Cu, Pb, Bi, As, Sb, Sn) must be removed by iron filings. H.H.S.

Zirconium determination in rocks. H. F. HARWOOD. *Tids. Kjemi Bergvesen*, **12**, 23 (1932); abstracted in *Sprechsaal*, **66** [51], 871 (1933).—After disintegrating the powdered sample with $HClO_4$ and H_2F_2, the residue (which was not attacked) contains the main quantity of zirconium and is melted with Na_2CO_3. The melt is treated with water and the insoluble melted with $Na_2S_2O_7$. The cooled melt is dissolved in diluted sulfuric acid; the Zr is precipitated in the solution with Na_2HPO_4 in the usual way after treating with H_2O_2. The $HClO_4$ solution obtained at first is also treated with H_2O_2 and Na_2HPO_4 and the sediment is added to the chief amount. M.V.K.

Rhenium sesquioxide, Re_2O_3. W. GEILMANN AND FR. W. WRIGGE. *Z. anorg. allgem. Chem.*, **214** [3], 239–43 (1933).—The methods of preparation and the chemical properties of this compound were determined. L.T.B.

Rhenium trioxide and rhenium dioxide. WILHELM BILTZ. *Z. anorg. allgem. Chem.*, **214** [3], 225–38 (1933).—The methods of preparing the two oxides are given with the chemical and physical properties. X-ray crystal studies are also included. L.T.B.

Planning for the collection of standardization data. J. R. TOWNSEND. *Proc. A.S.T.M.*, **33** [Part I], 770–85 (1933).—The important considerations in solving problems involving the collection of standardization data which have been in successful use are presented and recommended. R.A.H.

Factors in the presentation and comparison of particle-size data. E. J. DUNN, JR., AND JOHN SHAW. *Proc. A.S.T.M.*, **33** [Part I], 692–703 (1933); for abstract see *Ceram. Abs.*, **12** [12], 409 (1933). R.A.H.

Standardization of volumetric solutions. JULIUS GRANT. *Chem. & Ind.*, **53** [4], 76–77 (1934).—G. describes three classes of standards, (1) the ultimate standard, (2) working standards, and (3) secondary working standards. A.J.M.

Possible source of error in determining symmetry from optical extinction angles. MAX H. HEY. *Mineralog. Mag.*, **23** [141], 367–70 (1933).—During an optical examination of mesolite crystals with a view to determining their symmetry, H. was puzzled to find that whereas mesolite has generally been described as anorthic, on optical evidence he could detect no trace of inclined extinction in the prism zone. This study reveals the probable causes of the discrepancies and the precautions necessary for their avoidance. A.K.

Glass electrode potentiometer system for determining the p_H values of weakly buffered solutions such as natural and treated waters. JOHN O. BURTON, HARRY MATHESON, AND S. F. ACREE. *Bur. Stand. Jour. Research*, **12** [1], 67–73 (1934); R.P. 634. R.A.H.

Nomogram for the conversion of potentiometer readings to hydrogen-ion concentration. ALEC WEBSTER. *Chem. & Ind.*, **53** [2], 38 (1934).—W. gives the formula for constructing a nomograph chart and explains the use of the completed chart. Illustrated. A.J.M.

BOOK REVIEWS

The Physical and Chemical Principles of Ceramics (Die physikalischen und chemischen Grundlagen der Keramik). HERMANN SALMANG. Technical Institute, Aachen. Julius Springer, Berlin, 1933. 229 pp. 87 figs. This book represents an attempt to collect and summarize some of the outstanding data relating to ceramics. About one-half of the book is devoted to the subject of clays which are divided into two groups, the residual feldspathic clays and the allophanoids. The latter receive but little attention. A classification of clays such as that of Orton is not attempted, nor are they classified on the basis of their physical properties as has become the custom in this country. The physical and chemical properties of the clays are considered in detail with reference to the measurement of grain size, adsorption and capillarity, defloccuiation and coagulation, chemical reactions, drying, shrinkage, the effect of heat, inversions, and mullite formation. These subjects are treated from the modern point of view and with but few references to the older literature. A very satisfactory summary is given of the properties of silica. The topic of glazes receives brief attention. About 90 pages are devoted to the properties of ceramic products including brick, refractories, insulating materials, terra cotta, earthenware, stoneware, and porcelain and steatite products.

The writer has collected a great deal of material widely scattered through the literature and deserves much credit for having presented it in an orderly manner and from the modern point of view. It is of interest to note that the references to American authors are numerous.

The book should be a useful addition to a ceramic library. A.V.BLEININGER

Raw Materials of the Fine Ceramic Branches (Rohstoffe der Feinkeramik). WILLIAM FUNK. Julius Springer, Berlin, 1933. 334 pp. 69 figs. This book, which in its scope goes considerably beyond that indicated by the title,

is divided into three parts. The first, 176 pages, deals with a general descriptive discussion of ceramic materials, principally clays, silica, feldspars, alumina, cyanite, etc. A classification of clays, as we understand it, is not attempted. No reference is made to the division of kaolins into nacrite, dickite, and kaolinite-anauxite by Ross and Kerr. Much attention is paid to the mining and preparation of the raw materials, a subject which is treated with critical appreciation and which includes summaries of the latest researches.

The second part, 44 pages, concerns itself with the incorporation of the raw materials into bodies and glazes and is an excellent piece of work. The same praise may be given the third part which treats of the bodies and glazes of the specific ceramic products. Although this section covers but 76 pages, it is packed with a surprisingly large amount of information concerning industrial practice. The examples of body and glaze compositions are well selected. The references to the European and American literature are numerous.

The book throughout shows excellent discrimination on the part of the author in the selection and treatment of his topics, and it has an air of nonacademic freshness due perhaps to the fact that Dr. Funk is the plant director of the Meissen State Porcelain Factory.

The book is recommended to all who are interested in the plant operation of the fine ceramic industries.

A. V. BLEININGER

BOOK

Thin-Section Mineralogy. AUSTIN F. ROGERS AND PAUL F. KERR. 311 pp. Price $3.00. *Mining & Met.*, **15** [326], 105 (1934); for review see *Ceram. Abs.*, **13** [3], 71 (1934). E.J.V.

PATENTS

Process for manufacturing boric acid. EMIL FRANKE (Chemische Fabrik Grunau Landshoff & Meyer A.-G.). U. S. 1,944,598, Jan. 23, 1934.

Manufacture of sodium aluminate. ALUMINIUM, LTD. Brit. 403,719, Jan. 10, 1934.

Method of producing sodium aluminate solutions. E. L. RINMAN. Brit. 404,028, Jan. 17, 1934.

Treatment of clays with acids. W. W. GROVES (Merrimac Chemical Co., Inc.). Brit. 404,991, Feb. 7, 1934.

General

Presidential Address. J. C. HOSTETTER. *Bull. Amer. Ceram. Soc.*, **13** [2], 34–39 (1934).

Collegiate ceramic education: editorial in honor of the fortieth anniversary of the founding of America's first collegiate school of ceramics. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **13** [2], 31 (1934).

Economy and effectiveness in applied science instruction. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **13** [2], 33 (1934).

Necrology: E. W. Washburn. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 49 (1934).

Schedule for trip to Spruce Pine, N. C.: Joint Meeting American Ceramic Society and Electrochemical Society. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 47–48 (1934).

H. W. Gillett address before Refractories Division. *Bull. Amer. Ceram. Soc.*, **13** [2], 49 (1934). **C. A. Philhower talks on "Indian Pottery."** *Ibid.*

Report of Committee on Publications, 1933–1934. LOUIS NAVIAS. *Bull. Amer. Ceram. Soc.*, **13** [2], 49–50 (1934).

Report of Committee on Geological Surveys. W. M. WEIGEL. *Bull. Amer. Ceram. Soc.*, **13** [2], 50–52 (1934).

Audit report of the American Ceramic Society. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 53–54 (1934).

American Ceramic Society Student Branch activities. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 55–56 (1934).

W. T. Levitt gives Glass Division talk on "Flame Working of Glass." ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 56 (1934).

Canadian Ceramic Society Annual Meeting. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 56 (1934).

Ceramic Department; University of Illinois; adds administration option. ANON. *Bull. Amer. Ceram. Soc.*, **13** [2], 56 (1934).

The American Ceramic Society and Art. ANON. *Art*,[1] **27** [1], 40 (1934).—The tentative program of the Art Division at the 1934 Annual Meeting of the Society is given in this article. E.B.H.

Report on fired clay. HENRI GILARDONI. *Céramique*, **36** [545], 185–91 (1933).—In studying the abnormal shrinkage of molded clay, G. finds that (1) the percentage shrinkage is different in different directions, (2) the percentage of water has little or no effect, (3) structural changes as observed microscopically are small, and (4) the phenomena are probably due to a return to original form after molding. M.H.B.

Power costs by oil engine and electric motor. J. V. BRITTAIN. *Brit. Clayworker*, **42** [501], 298–99 (1934). R.A.H.

Accurate methods of determining the number and size-frequency of particles in dusts. H. L. GREEN. *Jour. Ind. Hygiene*, **16** [1], 29–39 (1934).—Accurate sedimentation methods are described for determining the number and size-frequency of particles in dust clouds. These methods are intended for fundamental research on the physical nature of dusts which produce pulmonary disease, and they provide simple and accurate means for testing the efficiencies of dust-sampling apparatus in the laboratory. They are most suitable for clouds containing not less than 1000 particles per cc., although they can be extended to clouds containing not less than 100 particles per cc.; they cover the whole size range down to 0.2μ diameter. Methods for counting the particles under a microscope of high resolving power and for rapidly determining the size-frequency of particles by use of a comparator graticule are described. The errors and limitations of the methods are

[1] See footnote, p. 79.

described in detail. The accuracy of the counting process was confirmed by comparison tests with the ultramicroscope on artificially generated clouds containing particles 80% of which were below 2μ in diameter. E.J.V.

Design and operation of a dust control system for use with pneumatic rock drills on open excavation. THEODORE HATCH, HENRY WARREN, AND GEORGE S. KELLEY. *Jour. Ind. Hygiene*, **14** [7], 246–54 (1932).—An investigation of the practical use of the Kelley traps for the control of dust generated by pneumatic rock drills was made. The plant was designed for use with forty drills and the amount of dust collected varied from 1.5 to 4 tons per day, the average being approximately 3 tons. The dust-collecting plant included two stages of separation, (1) a primary chamber for the removal of coarse material and (2) cloth screen filters having a net filtering area of approximately 1000 sq. ft., thus giving a rate of filtration of about 3 cu. ft. per min. for each square foot of filter surface. The filters were cleaned 4 to 10 times daily by manually operated shaking devices. The overall efficiency of collection was 99.7%, resulting in a dust concentration in the discharge air of from 10 to 25 million particles per cubic foot. The use of exhaust hoods was found to increase the speed of drilling from 11 to 21% and to effect a general improvement in working conditions. The cost of operation, however, was estimated to be only $2.21 per drill day, which represents an additional cost per foot drilled of 6.3%, or 1.05% of the cost per cubic yard of stone removed. Illustrated. E.J.V.

Application of the Kelley trap to underground drilling operations. THEODORE HATCH, J. W. FEHNEL, HENRY WARREN, AND GEORGE S. KELLEY. *Jour. Ind. Hygiene*, **15** [1], 41–56 (1933).—An investigation of the dust-collecting efficiency of the Kelley trap on rock drills of the Ingersoll-Rand N-75 type was made. Results of the tests indicate that for horizontal and down drilling, a rate of air flow of 200 cu. ft. per min. through the hood is sufficient to reduce the dust concentration at the breathing zone to below 10 million particles per cu. ft. of air. The average count obtained with the drifter in the stoping position was 11.6 million, but with modifications in the hood, it has been applied to the stopehamer with satisfactory results. Hoods and supporting devices for the drifter and stopehamer are described. Dust counts obtained with wet drilling, using both the South African and American type wet drills, were higher than those given by the blower-type drill equipped with an exhaust hood, and the dust concentration in the general mine air was found to build up more rapidly. Speed of drilling was found to be 40% higher and the overall footage 8 to 26% higher in the case of the blower-type drill compared with the American and South African type wet drills. Need for efficient and compact dust disposal plants for underground work is pointed out. Illustrated. E.J.V.

Equipment shows progress in respiratory protection. R. H. FERGUSON. *Nat. Safety News*, **28**, 37 (Oct., 1933); abstracted in *Ind. Hygiene Abs.*, **16** [1], 14 (1934).—Devices for protecting the worker from dusty and gaseous atmospheres are (1) respirators, (2) gas masks, (3) hose masks, and (4) self-contained oxygen breathing apparatus. F. describes each of the four devices. In general, he gives their construction, operation, life, care necessary in use, objections, atmospheres in which they should be used, etc. E.J.V.

Occupational cutaneous conditions in enamel workers. A. DOLGOW. *Sovet. Vest. Dermat.*, **29**, 114 (Feb., 1931); abstracted in *Ind. Hygiene Abs.*, **14** [4], 93 (1932).—In 42 workers (16 smelters and 26 helpers) at the Electroswet factory the following changes in the skins of the hands were observed: (1) mild erythema with slight scaling (16 cases); (2) dermatitis (18 cases); (3) legema (8 cases); (4) ulcerations (4 cases); (5) changes in the nails. An analysis of the filtrate of the enamel mixture revealed an alkalinity of from 16 to 32% of decinormal solution of hydrochloric acid. It was composed of silicic acid, cobalt, nickel, chrome, potassium, sodium, calcium, and aluminum. Fundamental skin tests according to the method of Jadassohn and Bloch showed specific sensitivity to the enamel mixture and its filtrate. In 6 of the affected workers tests were made with a 1% solution of nickel and cobalt sulfate; five of the patients reacted positively. These skin affections are caused by the physicochemical properties of the enamel, mechanical effect of the particles of enamel, chemical effect of its constituents that go over from the enamel into the solution, and finally, by the maceration and rubbing which increase the irritation. E.J.V.

Silicosis: minerals which cause it. W. R. JONES. *Engineering*, **136**, 527 (1933).—An examination was made for mineral residues in the lungs from a number of persons whose deaths had been certified as due to silicosis. It was found that SiO_2 in the uncombined state (quartz, etc.) is not the chief cause of the disease. Fibrous minerals, such as sericite, sillimanite, tremolite, chert, pumice, etc. are the real cause. One grain of quartz will contribute as much SiO_2 to the chemical composition of the residue as 1630 fibers of sericite. H.H.S.

Review of silicosis. ADELAIDE ROSS SMITH. *N. Y. State Dept. Labor Ind. Bull.*, **12**, 224–26 (Sept., 1933); abstracted in *Ind. Hygiene Abs.*, **16** [1], 9 (1934).—Total silica in a sample of dusty air may be determined chemically but petrographic analysis is needed for determining the free silica content. With this content known, the total dust is determined by counting the particles microscopically in samples taken with the Owens sampler or with the Greenburg-Smith impinger. The problem of silicosis is attacked by securing such combinations of the following measures as feasible: (1) substitution of non-silicosis-producing material, (2) inclosure and segregation of dusty processes, (3) local exhaust ventilation for the removal of dust at the point of origin, (4) suppression of dust by water, (5) general artificial ventilation, (6) plant cleanliness, (7) direct protection of the worker with masks and helmets, (8) alternation of work, (9) medical supervision, and (10) education. Dust counting to check the efficiency of measures should be a part of preventive programs. E.J.V.

Danger to health from grindstone dust with special reference to artificial stone and silicosis. V. MENSLAGE. *Zentr. Gewerbehyg. Unfallverhütung*, **18**, 123–25 (May, 1931); *Ind. Hygiene Abs.*, **14** [3], 67–68 (1932).—In grinding with artificial stone the "wear" proportion of the article ground to the stone is as 1:45 (in parts by weight) as compared with the much greater 1:5 to 1:10 with

natural stone. From a purely physical consideration any dust in inordinate amount is harmful but silicosis, generally speaking, can arise only from natural sandstones. E.J.V.

Ten years with a works council. C. J. STUART. *Factory Management & Maintenance*, **92** [1], 1–4 (1934). J.L.G.

Ceramic industry possibilities. ANON. *Manufacturers Rec.*, **102** [8], 44 (1933).—The vast resources of raw materials of the South are cited as possibilities for the manufacture of ceramic products. E.J.V.

Ceramic research reviews its work of 1933. ANON. *Ceram. Ind.*, **22** [2], 95 (1934).—A brief review of the work of the Bureau of Standards on optical glass, particle sizing in whiteware, refractories, measurement of moisture expansion, and cooling stress on enamels is presented. E.J.V.

Tendencies of the progress realized in ceramics. R. BARTA. *Chim. & ind.* [Special No.], **29** [6], 855–60 (June, 1933).—The chief topics discussed are (1) progress in plant equipment, (2) methods of production, (3) thermal economy, and (4) mass production. M.V.K.

Ceramic industry in Wales. ANON. *Times Eng. Supp.*, **33**, 31–32 (Oct. 28, 1933).—Ceramic articles include the lime and cement, clay and marl, silica, and firebrick industries in Wales. H.H.S.

BOOK REVIEW

Ceramic Technology. Vol. II. P. P. BUDNIKOFF. State Scientific Technical Publication, Charkov, U.S.S.R., 1933. 529 pp., 320 illustrations. This volume deals with (1) modern methods of forming ceramic ware, (2) drying and firing glazes and enamels, (3) refractories and Dinas, (4) refractory materials for the glass and chemical industries, (5) the production of high-grade refractories such as magnesite, chrome, silicon carbide, etc., brick, (6) refractories for the coke and lime industries, (7) production of gypsum, and (8) list of factories making machinery for ceramic ware in U.S.S.R. This is a valuable scientific study of the ceramic industry from practical and theoretical viewpoints. For Vol. I see *Ceram. Abs.*, **12** [1], 40 (1933). A. A. ZAKHAROFF

PATENTS

Colored mineral product and process of making. T. POOLE MAYNARD. U. S. 1,944,294, Jan. 23, 1934. The process of preparing colored roofing granules comprises impregnating fired clay granules with a solution of an inorganic color intermediate and treating the impregnated granules with a solution of a color precipitant to effect the reaction of the color intermediate and the color precipitant to deposit a coloring material on and in the granules.

Roofing granule. E. H. NICHOLS. U. S. 1,944,800, Jan. 23, 1934. The method of coloring granules of raw shale consists in heating the granules, simultaneously treating the hot granules with aqueous solutions of ferrous sulfate and borax to cause evaporation of at least part of the water, and reheating the granules.